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SIGNAL CORPS MANUAL No. 1
—
HANDBOOK
OF
TELEPHONES
OF THE
SIGNAL CORPS, U. S. ARMY

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SIGNAL CORPS MANUAL, No. 1.

HANDBOOK

OF

TELEPHONES

OF THE

SIGNAL CORPS, U. S. ARMY.

U. S. Signal office

PREPARED UNDER THE DIRECTION OF BRIGADIER GENERAL A. W. GREELY,
CHIEF SIGNAL OFFICER, U. S. ARMY,

BY

MAJOR SAMUEL REBER,
GENERAL STAFF, SIGNAL CORPS, U. S. ARMY.



WASHINGTON:
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OFFICE OF THE CHIEF SIGNAL OFFICER.

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OFFICE OF

SUPERINTENDENT OF DOCUMENTS

Washington, D. C., Dec. 5, 1905

University of California,

Joseph G. Rowell, Librarian,

Berkeley, Cal.

Dear Sir:

Replying to your card of the 21st ultimo: the titles of the
Manuals of the U. S. Signal Corps are as follows:

2. Regulations for management of U. S. military telegraph lines, 1903.
3. Electrical instruments and equipments, 1903.
3. Electrical instruments and telephones, 1905.
4. Notes on laying, repairing, operating, & testing submarine cables, 1902
- ✓ 4. Handbook of submarine cables, 1905. (Forwarded to depository libraries Nov. 14, 1905)
5. (Not issued)
- ✓ 6. Manual of visual signaling, 1905 (Forwarded to depository libraries June 20, 1905)

Nos. 1, 2, the two editions of no. 3, and the first edition of no. 4 have not been supplied to this office for distribution to depository libraries.

Very respectfully,

CC Farrell
Superintendent.

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SIGNAL OFFICE, WAR DEPARTMENT,
WASHINGTON, *April 2, 1904.*

The following instructions for the use of telephones will replace all others heretofore issued by this office.

Officers and men of the Signal Corps will thoroughly familiarize themselves not only with the ordinary methods of operating telephone lines, whether the instruments are bridged or in series, but will also acquaint themselves with the construction of the various types of telephones herein described.

Every officer and noncommissioned officer of the Signal Corps should be able to readily locate and remedy faults, whether they are in the instrument, in the battery, or on the line.

A. W. GREELY,
Brigadier General, Chief Signal Officer, U. S. Army.

(3)

PREFACE.

In compliance with the instructions of the Chief Signal Officer of the Army, this handbook has been prepared to describe, in as simple and nontechnical language as possible, the construction and operation of the various types of telephones and switch boards supplied by the Signal Corps for the use of the Army; consequently no reference to the engineering principles involved is made. The telephone is daily becoming of more and more importance to the Army. Nearly all of the apparatus described in this book has been designed by the officers of the Corps to cover the special necessities that arise in the military service, where the requirements are quite different from those of ordinary commercial life. In the field apparatus strength and portability are the predominating features of design, while the efficiency of talking and ringing circuits is maintained. A part of the field apparatus is intended to utilize the principles of simultaneous telegraphy and telephony over the same circuit. Since the issuance of the instructions of 1901, the types of telephones and switch boards have all been standardized, and only those which are issued at present are described. I am indebted to Mr. R. A. Klock, electrical engineer, Signal Corps, for the material of the text and the figures contained in Chapter VII.

SAMUEL REBER,
Major, Signal Corps.

WASHINGTON, D. C., *April 2, 1904.*

TABLE OF CONTENTS.

	Page.
CHAPTER I.—General instructions.....	9
CHAPTER II.—Theory of the telephone.....	11
CHAPTER III.—Description of the component parts of various types of telephones	15
CHAPTER IV.—Buzzers and field telephones	34
CHAPTER V.—Switch boards.....	41
CHAPTER VI.—Location and elimination of trouble in telephones and switch boards	59
CHAPTER VII.—Inductive and other disturbances in telephone circuits...	65



HANDBOOK OF TELEPHONES.

CHAPTER I.

The following instructions are issued for the guidance of all those who use telephones supplied by the Signal Corps, United States Army:

GENERAL DIRECTIONS.

The telephones issued by the Signal Corps, United States Army, to the various signal officers are furnished for use on ranges during the prescribed target season, for fire control communication at artillery posts, and for facilitating intercommunication at the various garrisons and in the field.

All officers to whom instruments are issued will thoroughly familiarize themselves with their construction, use, and means of discovering and correcting the usual faults that may develop during service, and they are charged with seeing that the following rules are strictly enforced:

The dismounting of any part of the telephone, even by experts, will only be resorted to when absolutely necessary to secure satisfactory communication.

Only those who are familiar with the construction will be allowed to disconnect the various parts or dismount the instrument. The wiring of the armatures, coils of call bell, and bobbins of receiver and induction coil should never be unwound. The diaphragms of the receiver and transmitter are not to be disturbed, e. g., by poking with a pencil, etc. If the transmitter is not working properly, it is not to be knocked or shaken up. The battery connections and tops of cells are to be kept clean and free from salts, solutions up to proper strength, and water up to water line on cells. In case of failure to work, all circuits, both inside and out of the instruments, should be carefully inspected and tested. In case the remedy can not be applied at the post, a report of the circumstances should be made to the signal officer of the department.

The series instrument is connected as follows: The line post to line and ground post to ground plate, which should be of ample size and located in damp earth. One end of the wire should be firmly soldered to the ground plate and the other attached to the ground post. The ground wire should be as straight as possible, without unnecessary bends or convolutions.

The line post is the right-hand post, looking at the instrument on top of the magneto call box. The ground post is the left-hand one.

If the telephone is supplied with a plate lightning arrester, the center post should be connected by a wire to the ground wire outside of the instrument. If the instrument is of the bridging type and the circuit a metallic one, connect both right and left hand posts on top of magneto to the line wires and ground the middle one, which is on the lightning arrester. In case the line is a single wire, connect the same way as with the series instrument. Where there is any danger from power circuits, the instruments should be properly fused.

During all storms, or when left on the target range over night, lightning arresters should be short-circuited by inserting the plug in the hole between the plates.

When using the instrument, call by briskly turning the handle in the call box and wait until the call is answered by a ring before unhooking the receiver, if the line is not connected to an exchange. If connected to an exchange, as soon as the ring has been made, unhook the receiver and listen for "Central's" call. When through talking, hook up the receiver and ring off. *Never leave the instrument with the receiver off the hook.*

CHAPTER II.

THEORY OF THE TELEPHONE.

In the act of speaking, the vocal cords are lengthened and shortened by muscular action. This lengthening and shortening causes air vibrations in the mouth and air passages, from which waves of sound proceed. When these wave sounds fall upon the drum of the ear, they are recognized by the auditory nerves as speech. If, instead of falling on the eardrum, these vibrations should fall upon a diaphragm which is capable of changing them into electrical vibrations, and there is some means of transmitting them along a line and again reproducing at the other end into similar air vibrations, we have the telephone. In order to understand the action of the telephone, it is necessary to define lines of force and explain two simple laws of magnetic induction. Lines of force are the imaginary lines which are supposed to surround a magnet and indicate by their position and number the direction and strength of its action. The laws of magnetic induction referred to are: First, if a number of lines of force thread or pass through a coil of wire, and this number is increased or diminished, a momentary current will flow in the coil; second, if a coil of wire be wound around a permanent steel magnet, and a current of electricity be sent through the windings, it will, if in a certain direction, increase the strength of the permanent magnet, and if in the opposite direction will diminish its strength.

To understand how a telephone works, let us take the simplest case of two telephone receivers, *A* and *B*, connected to the line as shown in Fig. 1.

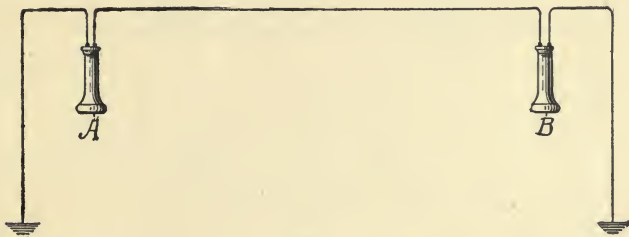


FIG. 1.

The telephone receiver (a more detailed description of which will be given later) consists of a soft iron diaphragm placed a short distance away from a permanent magnet. Around the diaphragm end of this magnet is wound a coil of fine insulated copper wire. The air vibrations caused by the act of speaking upon striking the iron diaphragm at *A* cause it to vibrate. The vibrations of this diaphragm produce changes in the number of lines of force which

thread through the windings of the coil. These changes, according to the first law, produce a current in the winding which will be of greater or less strength and in opposite directions, following the vibrations of the diaphragm. This varying current proceeds along the line, and when it arrives at *B* will increase and diminish the strength of *B*'s magnet. The variation of the strength of *B*'s magnet will produce a varying pull on *B*'s diaphragm and cause it to vibrate in a manner similar to the diaphragm of *A*. The vibration of the diaphragm at *B* is recognized as speech coming from *A*. The simple circuit shown in Fig. 1 would permit a person to talk or hear, as the case may be. The first modification of this circuit, Fig. 2, is to introduce two telephone receivers at the point *A* and two at the point *B*, all being in series, one serving as the transmitting and the other as the receiving instrument at each point.

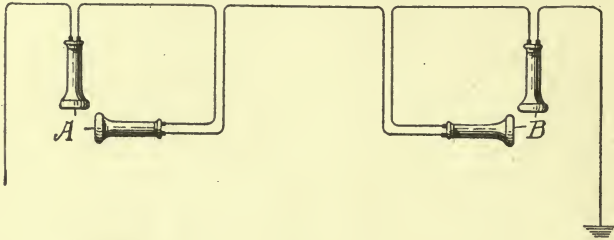


FIG. 2.

For certain reasons this type of receiver just described does not make a good transmitter, and in practice is replaced by a battery transmitter.

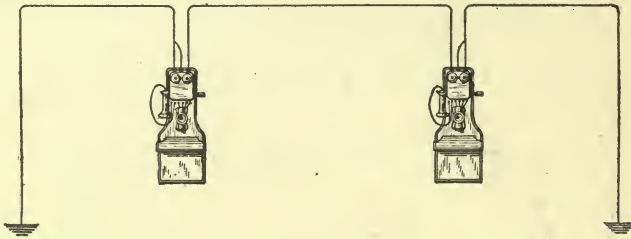


FIG. 3.

Fig. 3 shows a typical single-wire or grounded circuit supplied with two complete series instruments, and Fig. 4, a typical metallic circuit supplied with three bridging telephones.

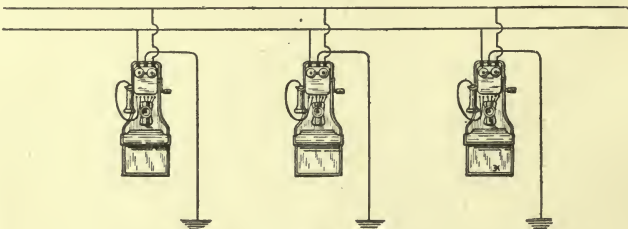


FIG. 4.

A complete telephone instrument consists of a receiver, battery transmitter, magneto generator, call bell, and certain switching devices, which are contained in the magneto-generator box.

BATTERY TRANSMITTER.

The battery transmitter depends for its action on the fact that a varying pressure changes the resistance of carbon. The transmitter consists of a number of carbon particles or granules in a proper receptacle with a means of varying the pressure upon the granules in circuit with a battery and the coarse-wire winding of an induction coil, which consists of a bundle of soft-iron wires surrounded by two windings of insulated copper wire, one being of coarse wire, with few turns, called the "primary," and the other of fine wire, with a large number of turns, called the "secondary," the latter being connected to the line. The relative position of these various parts of a battery transmitter is indicated in Fig. 5, in which *A* is the receptacle that contains the

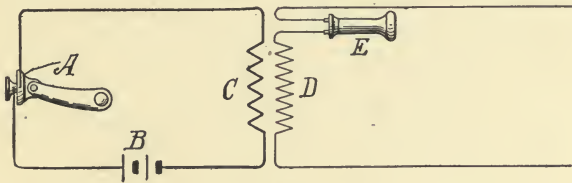


FIG. 5.

carbon granules through which the current from a battery, *B*, flows. *A* also contains a diaphragm which presses on the carbon granules, or is so connected with them as to vary the pressure as the air waves fall on it. *C* is the coarse and *D* the fine-wire winding of the induction coil, which is connected to the receiver *E* and the line. As the air vibrations fall on the diaphragm at *A*, they produce a change in the resistance of the carbon particles. This change of resistance causes the current flowing in the coarse-wire coil to fluctuate, thereby producing a fluctuating induced current in the fine-wire coil, which goes to the line and receiver and reproduces speech as has been explained before.

MAGNETO GENERATOR.

The magneto generator, or magneto as it is called, consists of three or four permanent steel magnets, rigidly connected together, with an armature so placed that it can be rotated between their poles. The armature consists of a core of soft iron which is wound with a coil of insulated copper wire whose terminals are connected with the line. The revolution of the armature changes the number of lines of force passing through it and produces a current that rings the bell.

The call bell consists of a permanent magnet which is so mounted as to magnetize a soft-iron armature and the iron cores of two coils of insulated wire over which it is pivoted. A thin rod is attached to the center of the armature and at right angles to it. Two bells are so placed that the hammer while vibrating will alternately strike each.

The series instrument, Figs. 8 and 10, is one in which the call bell and magneto are in series, or directly connected with the line and the receiver of the instrument, while the magneto is automatically short-circuited.

The bridging or parallel instrument is shown in Figs. 6, 7, and 9.

CHAPTER III.

DESCRIPTION OF THE COMPONENT PARTS OF VARIOUS TYPES OF
TELEPHONES.

Since the calling and talking part of the instrument are used alternately, there must be some switching device for changing from one to the other. When the instrument is not in use it must be ready to respond to a call, and when the talking circuit is used the resistance of the magneto and call bell must be cut out of the circuit. In addition to this, when the transmitter is not in use the battery current must be cut off from the transmitter, or else the battery, owing to the low resistance of the transmitter circuit, would soon exhaust itself and run down. To accomplish these various changes a switching lever is so designed as to be held down by the weight of the receiver. In this position the calling circuit is on the line, and when the receiver is unhooked the lever flies up, putting the receiver and secondary of the induction coil on the line, and the battery on the transmitter circuit. The lever arm or switch hook usually consists of a pivoted arm, which is spring-controlled, and when the transmitter is hooked up, its weight pulls the lever arm down and breaks the rear contacts. When the receiver is unhooked a spring throws the arm up and closes the listening and talking circuits.

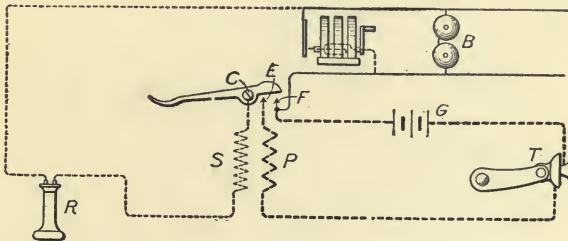


FIG. 6.

Figs. 6 and 7 show the ordinary arrangement of circuits and operation of the lever arm for the bridging type of telephone. The bell *B* and the magneto are permanently bridged across the line, but the armature circuit of the magneto is open, except when it is being used for calling a distant station. It will be noticed that the circuit from the line is through the receiver and secondary of the induction coil to the pivot of the lever arm, and when the arm is down both receiver and transmitter circuits are open. An incoming call will simply ring the bell *B*, and when a distant station is called, both the bell *B* and the distant one will ring.

When the receiver is unhooked, as shown in Fig. 7, the circuit is from the line through the receiver *R*, the secondary of the induction coil *S*, the pivot *C*, thence through back of switch arm to *F*, and from *F* to line, the other side of the line and the transmitter

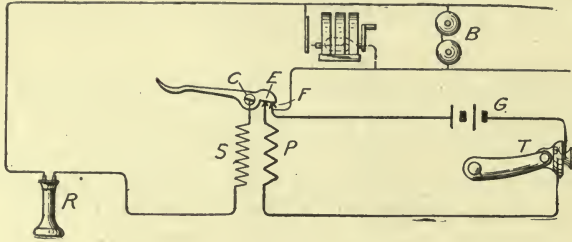


FIG. 7.

circuits being joined below the point *F*. The battery circuit is now from the battery *G* through the transmitter *T* and the primary of the induction coil *P* to *E*, then through the back of the switch arm to *F*, and thence back to battery.

In the series instrument when the lever arm is down the bell is in series with the line, but the magneto cut out by the automatic shunt *Y*.

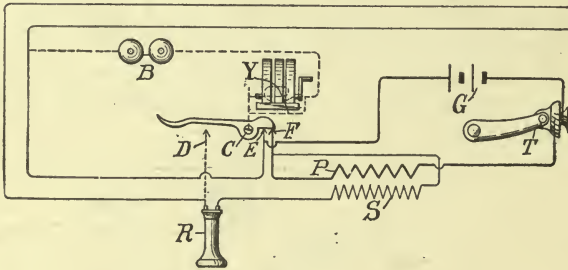


FIG. 8.

Fig. 8 shows the circuits in the series telephone when the receiver arm is up, thereby closing the rear and opening the front contacts. The circuit in this case comes from the line to *E*, from *E* through back of switch to *F*, and from *F* to *H*, thence through the secondary of the induction coil *S* and the receiver *R* to line or ground, the bell *B* and the magneto being cut out as the front contact *D* of the switch arm is open. The transmitter circuit is the same as in the bridging instrument.

WIRING OF BRIDGING TELEPHONE.

The wiring of a standard bridging set is shown in Fig. 9, where it is observed that both the bell and magneto are permanently bridged across the wires leading from binding posts 1 and 3. When the hook is up the listening circuit is as follows: From 1

through to 10, from 10 through switch arm and pivot to 8, from 8 through secondary of the induction coil to 9, from 9 to 5, from 5 through the receiver to 4, and from 4 to 3, and line. The talking

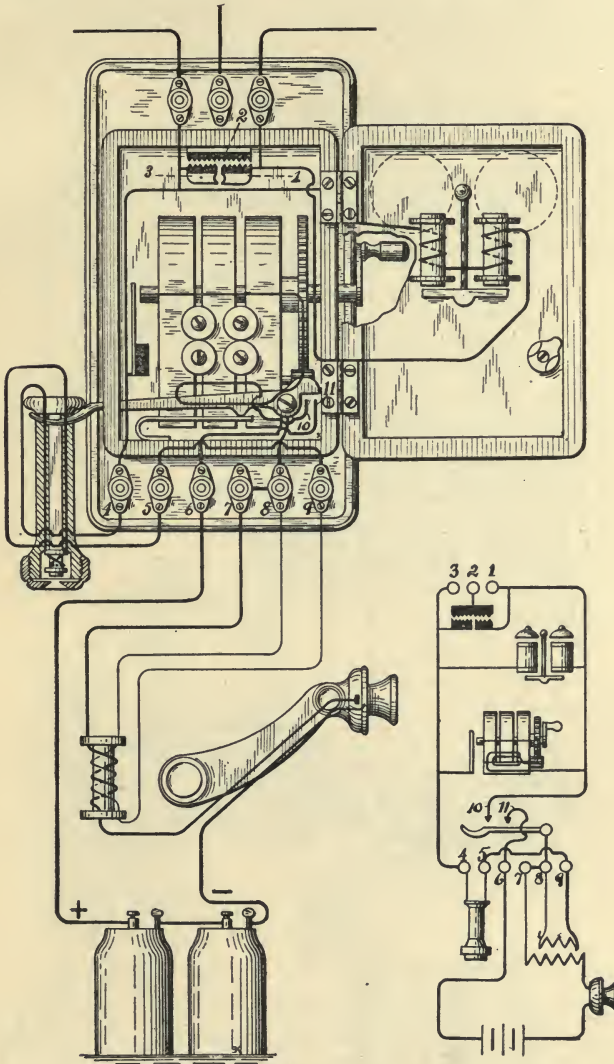


FIG. 9.

circuit, starting at the battery, is from the battery through the transmitter, then the primary of the induction coil to 7, and from 7 to 8, from 8 through pivot of switch and switch arm to 11, from 11 to 6, and from 6 to the other side of the battery.

A description of the connections in the transmitter arm will be given later.

WIRING OF SERIES TELEPHONE.

The wiring of the standard series wall instrument is shown in Fig. 10, and the following are the circuits: From binding post 1 a wire is led to the back contact 10. This circuit is bridged to the upper hinge of the magneto box, and passes from thence through

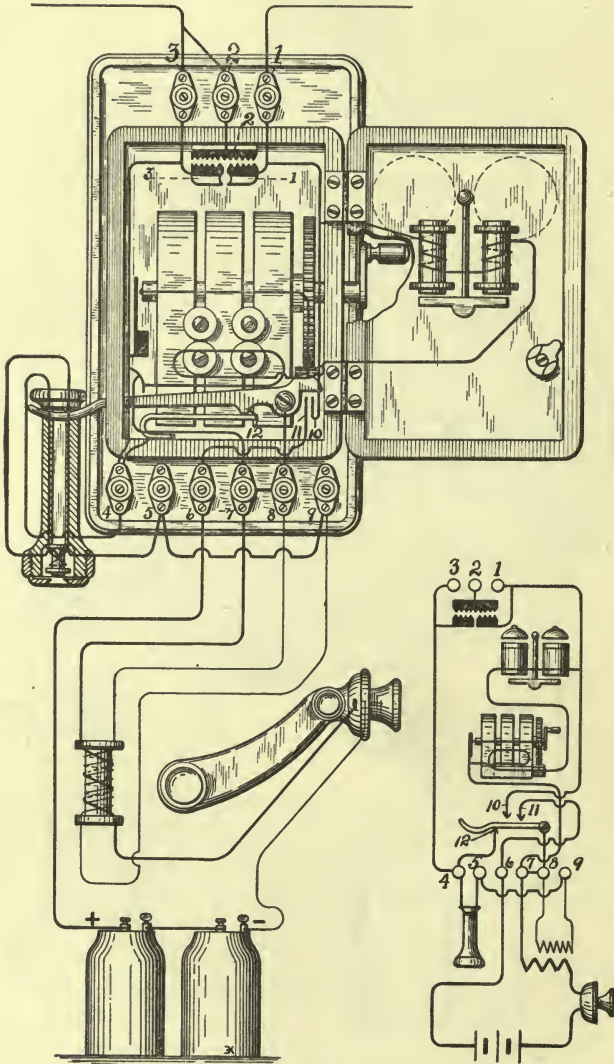


FIG. 10.

the windings of the call bell to the lower hinge and from this point through the automatic shunt and armature of the magneto and from there to post 7, from post 7 to post 8, through the secondary of the induction coil to 9, from 9 to 5, from 5 through the receiver

to 4, and from 4 to binding post 3, and also to the front contact 12 of the hook switch. The back contact 11 of the hook switch is connected to post 6, from thence through the battery to the transmitter, and from the transmitter to the primary of the induction coil to post 7. Post 8 is connected to the pivoted part of the hook switch. The interior wiring of the magneto is always properly connected up before issuing, and in case the instrument is dismantled from the backboard it may be reconnected by the following simple rule: Connect the receiver terminals to the two left-hand posts (looking at the instrument) on the bottom of the magneto, one side of the battery circuit to the left-hand middle post, the other side of the battery and of the primary coil to be connected together through the transmitter, while both leads from the secondary coil are connected to the two right-hand posts.

DESK SET.

Fig. 11 shows the circuits of the standard desk set. The hook switch when up closes the two clip springs $A A'$, which are mounted on the hard-rubber block B . The springs are connected by insulated wires passing through the hollow standard C to posts 7 and 9,

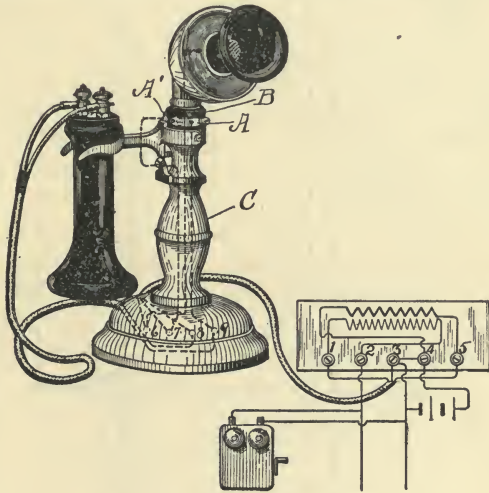


FIG. 11.

which, together with 6 and 8, are mounted on a hard-rubber block (not shown in the drawing) in the base of the instrument. One electrode of the transmitter is connected by an insulated cord to post 6 and the other grounded to the frame. The receiver cords are connected to 8 and 9, and the set is connected by a three-wire cable at 6, 7, and 8 to binding posts on the wooden block holding the induction coil. This block serves as a mounting for the induction coil and has five binding posts. The line with the magneto

bridged across it is connected to 2 and 3, the primary of induction coil to 4 and 5, the secondary to 2 and 1, the battery to 3 and 4, and the three leads from the instrument to 1, 3, and 5.

SERVICE TELEPHONE, 1902 MODEL.

The service telephone is a bridging set with magneto box that has the induction coil fastened in the top, and a transmitter of the

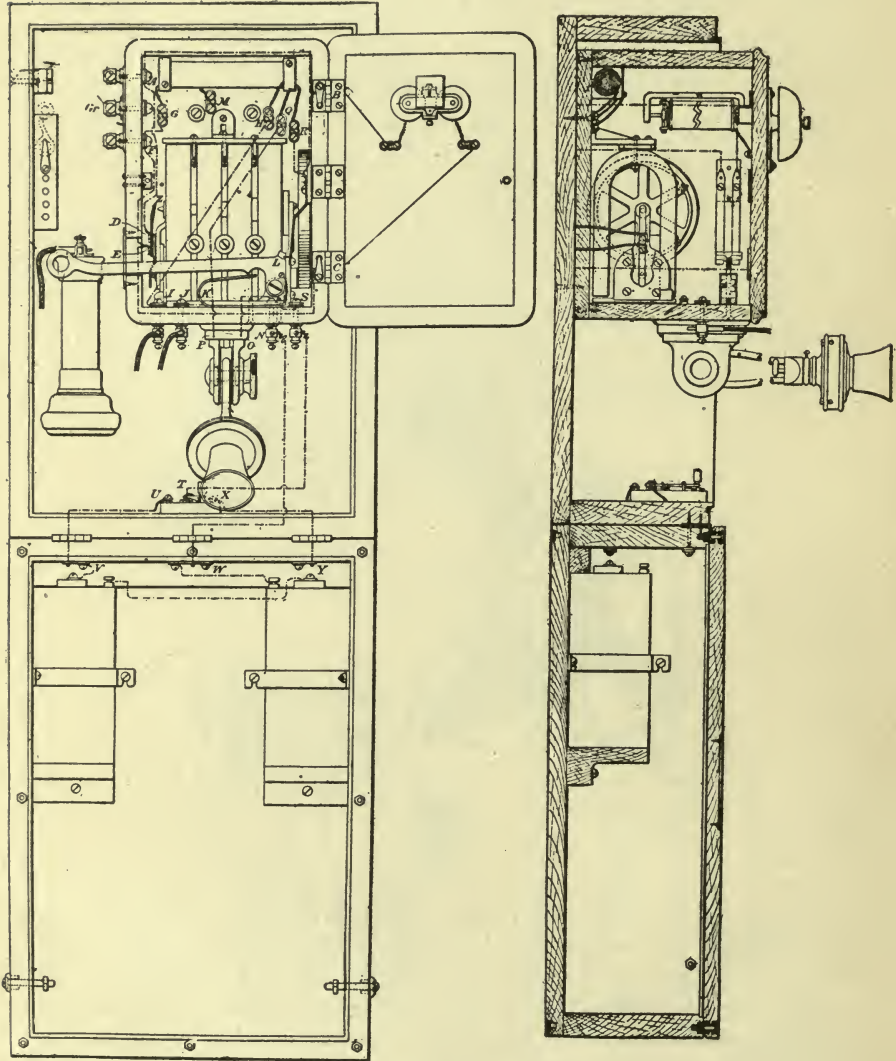


FIG. 12.

solid-arm type, fastened on the bottom. The magneto box is securely fastened in the upper half of the case, while two cells of

dry battery are screwed in its lower half. The box, when closed serves as a packing case for shipment. When the box is closed for shipment the transmitter arm is removed from the bottom of the magneto box and held by a clip in the battery half.

The containing box, Fig. 12, is of two halves securely fastened together by three strong hinges; each half is $16\frac{1}{2} \times 11\frac{1}{2} \times 5\frac{1}{4}$ outside measurement. The halves are so arranged that when the cover is closed the instrument is protected and ready for shipment. The box is locked by two screw bolts each fastened into a brass lug. When the instrument is packed for shipment the front board over the lower half of the box, as shown in the figure, is screwed to the back of the upper half. The back of the upper half is bored with four holes for the screws which hold it to the wall, and these screws and the magneto handle, when the instrument is ready for shipment, are placed in a small block of wood indicated in the figure on the left side of the upper half of the box.

On the bottom of the upper half is a two-point switch for changing from dry to wet batteries; when the switch is turned to the left the dry batteries are in circuit with the transmitter, and when turned to the right the wet batteries can be used when their terminals are attached to *W* and *Y*. The upper and lower of the three binding posts on the magneto are the line terminals, and the middle one, marked *Gr*, is the ground terminal.

The following are the circuits: An incoming ring will come from the line through *A*, around to the hinge *B*, thence through the bell to the hinge *C*, from the hinge *C* around to the other line post *F*. To ring, starting at one terminal of the armature *D*, from *D* around to *A*, where the circuit divides, going to line and through the bell, from line through *F* back to *E* and through the armature to its starting point *D*. When the switch arm is up the listening circuit is from *A* through the hinge *B*, and through the switch arm to *J*, from *J* through the receiver to *I*, from *I* to *H*, thence through the secondary of the induction coil to *G*, and from *G* to *F*, the other line terminal. The talking circuit, when dry batteries are used and the battery switch is on the contact *U*, is from one terminal of battery *V* through the hinge in the bottom of the box to *U*, from *U* through the battery switch arm to *T*, from *T* to the right-hand binding post in bottom of the magneto box, thence to *S*, from *S* through the switch arm and contact to *R*, from *R* through the primary of the induction coil to *Q*, from *Q* to *P*, and to one of the solid arms of the transmitter, thence back to the other solid arm to *O*, from *O* to *N*, and from *N* to *W* and the other side of the battery. In case wet battery is used the terminals are *W* and *Y* and the circuits as above.

In the 1901 model (Fig. 12-A) the dry batteries are placed in a small box below the magneto and behind the transmitter arm,

which, in this case, is shorter and permanently fastened to the bottom of the magneto box. The two-point switch in the 1901

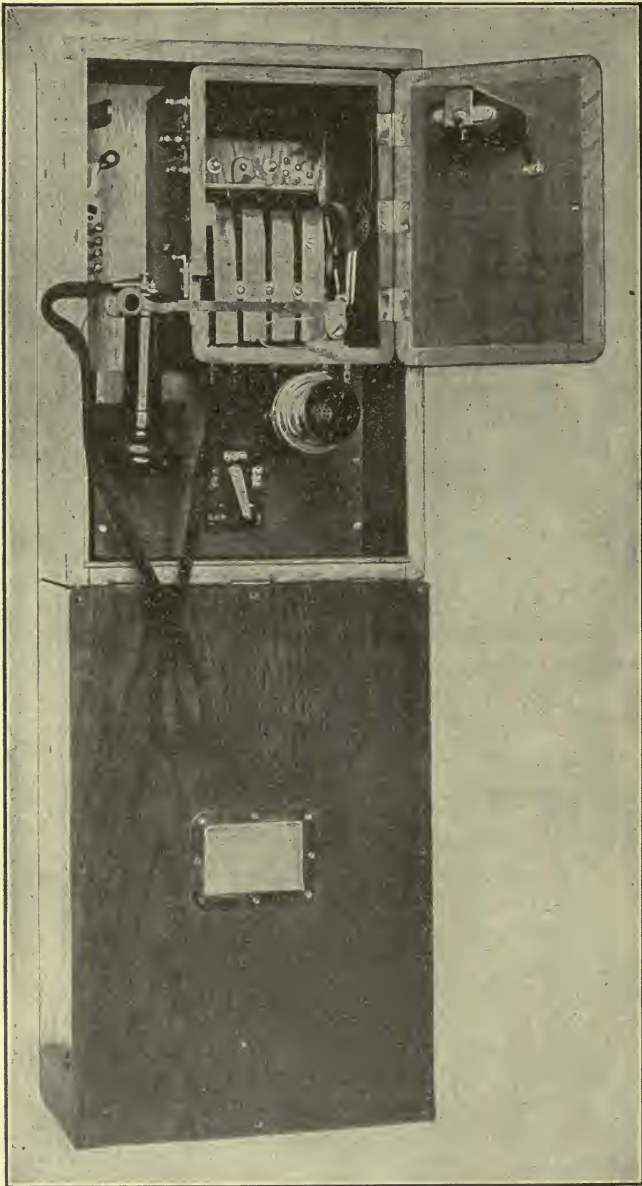


FIG. 12-A.

model is on the front of the battery box; the circuits are the same as in the 1902 model.

SCHMIDT MAGNETO.

In the Schmidt magneto, as shown in Fig. 13, the four permanent steel magnets *M* are slipped between projecting lugs, *A*, on the two cast-iron pole pieces *P*, which are bored to receive the armature, that consists of a coil of fine insulated wire, *B*, wound on soft-iron disks, *C*, that are mounted on the armature shaft *D*. One end of the coil is connected with a pin on the shaft at *E* and the other to the pin *F*, which is insulated from the shaft by a hard-rubber bushing, *G*. This pin rests on another insulated pin, *H*, which passes out through the end of the shaft and touches the spring *I*. The armature shaft is supported by the two brass castings *K K'*

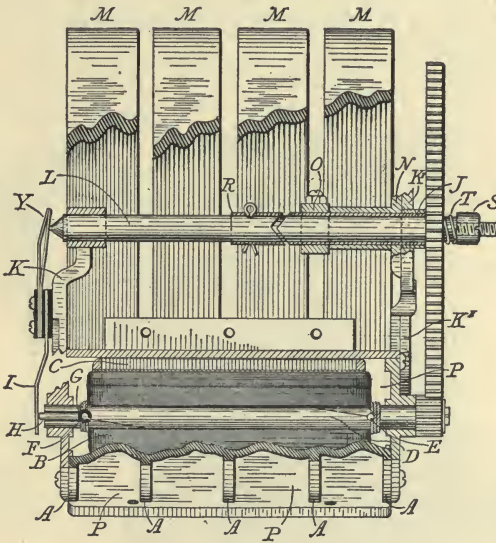


FIG. 13.

that are screwed to the ends of the pole pieces. The casting *K* terminates in a cylindrical bearing through which the driving axle *L* can move in the direction of its length. A steel sleeve, *J*, brazed to the driving gear, is slipped over the axle, and supported by the brass casting *N*, which is screwed to the inner face of the upper part of the casting *K'*. The brass collar *O* is fastened to the sleeve by a set screw and shouldered against the casting *N*; the sleeve *J* terminates in a knife-edged face that engages in the V groove of the steel collar *R*, which is fastened to the driving shaft by a pin. At the outboard end of the driving shaft is the nut *S*, between which and the gear wheel is a coiled spiral spring, *T*, slipped over the driving axle. The tendency of this spring is to keep the V groove of the collar *R* seated against the knife-edged end of the

sleeve *J*, and the end of the axle away from the spring *Y*. When the handle of the generator is turned the knife edge slips along the **V** groove and brings the end of the driving shaft against the spring *Y*, which is fastened to and insulated from *K*. The end of the armature winding, which is connected to the pin at *E*, is, consequently, connected through the frame of the magneto to the spring *Y*, which, with spring *I*, serve as terminals for the generator.

HOLTZER-CABOT MAGNETO.

The common form of Holtzer-Cabot magneto is shown in Fig. 14. Three or four permanent field magnets, *M*, are rigidly connected by two soft-iron pole pieces, *P* (one only being shown in the drawing), which are bored to receive the armature, that consists of a coil of fine insulated wire, *A*, wound on circular soft-iron disks, *B*, that are mounted on the driving shaft *C*.

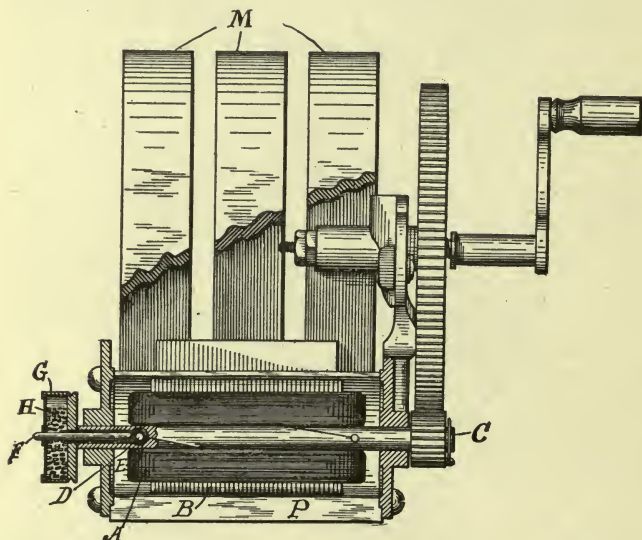


FIG. 14.

One end of the coil is connected with the shaft and the other to a pin, *D*, which is insulated from the shaft by the hard-rubber bushing *E*. This pin rests on another insulated pin, *F*, that passes out of the end of the shaft. At the end of the shaft a circular metal box, *G*, is fastened over the insulating sleeve, and is filled with short pieces of bare wire, *H*, which, when the shaft is at rest, lie upon it and short circuit the armature windings. When the shaft is in motion these pieces of wire are thrown clear of it by centrifugal force, and the armature winding is then connected to the calling circuit.

WESTERN ELECTRIC MAGNETO.

Fig. 15 shows the operation of the automatic shunt in the Western Electric Company's type of series magneto. The outboard end of the shaft *A* that carries the driving wheel *B* is turned down to a shoulder, *C*, which has a V-shaped groove cut across its face at a right angle to the driving shaft. In the rear of the bearing is a cylindrical box, *D*, that contains a coiled spring, *E*. This box is securely fastened to the shaft by means of set screws. The tendency of this spring is to force the shaft against the spring *H*. A driving handle, *F*, is slipped over the front end of the shaft. This handle is fitted with a stud, *G*, with a knife-edge face that engages in the V groove on *C*. As the handle is revolved, the

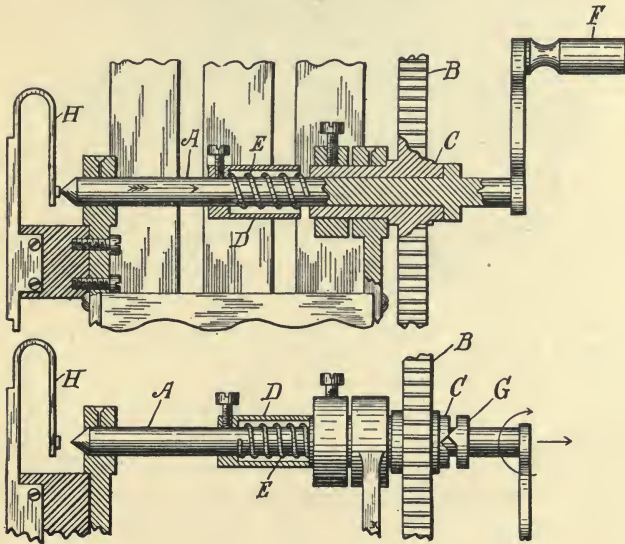


FIG. 15.

knife edge slips along the V groove, compresses the spring *E*, and throws the end of the shaft away from the spring *H*, as shown by the arrow. This spring *H* and the gear wheel being in metallic connection with the armature, when the handle is turned the short circuit around the armature is broken.

The call bell of the Holtzer-Cabot type of magneto is shown in Fig. 16. The two bells *A* are fastened to the posts *B* by the screws *C*. These posts are part of the base casting, which is secured to the front of the door by screws. The permanent steel magnet *D* is so shaped as to inclose the windings of the bell and is fastened to the door by the screws *E*. The cores of the coils are of soft iron and fastened to the front end of the permanent magnet by the screws *F*, and are held in their proper position by the flat soft-iron

connecting piece *G*, which is part of their magnetic circuit. The armature *H* is pivoted to the brass supporting piece *J*, which in its turn is fastened to the rear end of the permanent magnet by the hexagonal-headed screw *K* that serves to adjust the distance of the armature from the cores of the windings. Attached to the pivoted armature is a rod which, passing through the door of the

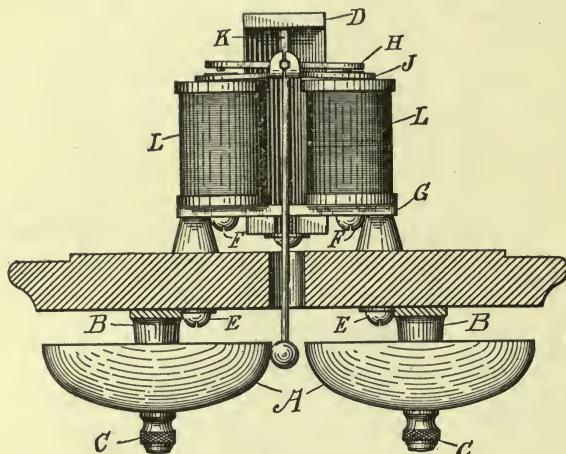


FIG. 16.

box, carries a striker, and, as the armature oscillates alternately, strikes each bell. The coils *L* are wound in the same direction, and as both cores have been polarized alike by the permanent magnet the calling current in the windings will strengthen the pull of one and weaken the pull of the other core on the armature, and, since it is alternating in character, will cause the armature to vibrate from one to the other.

BIPOLAR RECEIVER, AMERICAN BELL TELEPHONE COMPANY.

This receiver is shown in Fig. 17. The shell *A* and ear piece *B* are of hard rubber and clamp between them the soft-iron diaphragm *D*. The magnet consists of two separate steel bars, *FF*, connected at the back end by a soft-iron yoke, *I*, which is made out of a short piece of round rod and which is held in place by the rivet *R*, which passes clear through both steel bars and the yoke. The steel bars are so magnetized that the south pole of one and the north pole of the other are toward the diaphragm. These ends are held in position by an adjustment block, *H*, of brass or composition, which has two segmental projections extending outward between the steel bars. On the outer surfaces of these segmental projections is cut a thread, which thread fits the thread *g*, cut upon the interior surface of the shell *A*. At the front end of the

steel bars, between the segmental projections, are the soft-iron pole pieces *PP*, which are held in position by the brass bolt *b*, that also holds the block *H*. The space between the steel bars, the yoke, and the adjustment block *H* is filled by the block of wood *W*.

On the pole pieces *PP* are wound the coils *GG*, which are made of fine insulated wire. The ends of this wire are connected by the lead wires *LL* to the binding posts *JJ*. The screw thread *g* serves

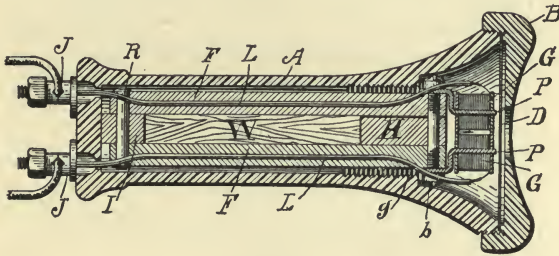


FIG. 17.

the double purpose of holding the magnets in place in the shell and of adjusting the distance between the pole pieces and the diaphragm. When this distance is once correctly adjusted it should not be altered, and in this receiver the adjustment is first made, then the lead wires *LL* are inserted and soldered to the magnet wires. If at any time it should become necessary to remove the magnet from the hard-rubber shell, the lead wires *LL* must first be removed before attempting to turn the magnet in the screw thread *g*.

SCHMIDT BIPOLAR RECEIVER.

This receiver is shown in Fig. 18. The shell is of two pieces, the tube *A* of hard rubber and the cap *B* of metal, the ear piece *C*

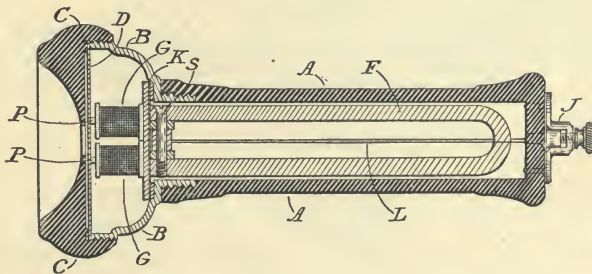


FIG. 18.

being of hard rubber screwed over the outside of the cap in the usual manner, thereby binding the diaphragm *D* between it and

the edge of the cap. The magnet is made of a single piece of steel, *F*, doubled upon itself in horseshoe form so as to present a north and south pole to the diaphragm. The pole pieces *P P* are of soft iron and secured to the magnet by the screw *S*. On the pole pieces are wound the coils of *G G*, of fine insulated wire, the ends of which are soldered to the lead wires *L*, the other ends of which are connected with the binding posts *J*. Three washers, *K*, one of soft iron and two of fiber, are slipped between the bobbins and the poles of the magnet, the lower of the three washers being seated on a shoulder in the cap *B*, and held in place by two screws, not shown in figure, passing through the washers into the hard-rubber tube *A*, thereby holding the magnet and bobbins in the shell.

THE WATCH-CASE RECEIVER.

This receiver, shown in Fig. 19, is bipolar and used as a head receiver for switch-board work, in the combined receiver and transmitter and in certain types of field apparatus. The figure shows a section and a view with the cover and diaphragm removed. It consists of a metal case, *A*, on which is screwed a hard-rubber ear piece, *B*, clamping the diaphragm *C* in the usual manner.

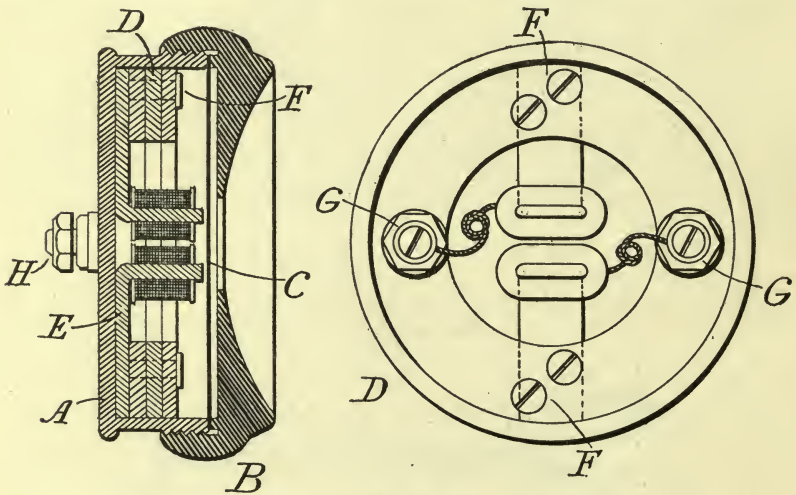
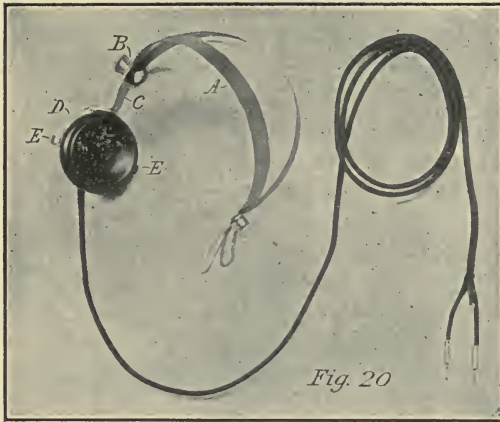


FIG. 19.

The magnets consist of three steel rings, *D*, between the lower of which and the metal case *A* the curved soft-iron pole pieces *E* are inserted and fastened to the magnets by the screws *F*. The bobbins are slipped over the ends of the pole pieces, and the windings are brought to the two screws *G*, which extend through the magnets and terminate in the binding posts *H*. When used as a head receiver it is mounted as shown in Fig. 20. The headpiece

consists of two flexible metal straps, *A*, of the form shown in the figure, which are pivoted at *B* to the short connecting piece *C*, that is in turn pivoted to the fork *D*, that contains two studs, *E*, that are



sprung into the metal case of the receiver, which is free to turn around these studs, the three pivots permitting the receiver to be fitted and adjusted to any head.

WHITE SOLID BACK.

The White solid-back transmitter of the American Bell Telephone Company is shown in Figs. 21 and 22. The transmitter is inclosed in a metallic cover, *A*, which is attached to a movable

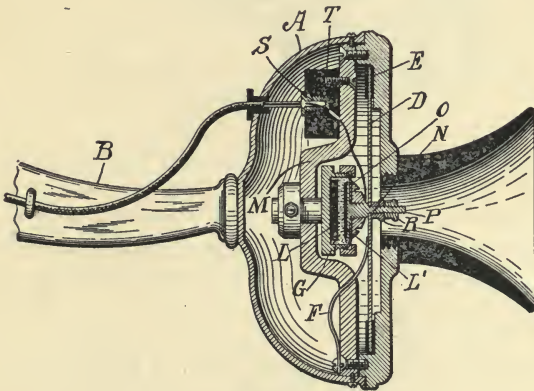


FIG. 21.

cast-iron arm, *B*, that is pivoted to the case *C*, containing induction coil *e*. The case *A*, which contains the working parts of the transmitter, is made in two sections. The front section holds a

circular soft-iron diaphragm, *D*, whose edge is incased in a soft-rubber ring, *E*, and held in place by damping spring *F*, screwed to the front part of the case. A hollow cylindrical box or a case, *G*, of two parts screwed together, holds two carbon disk electrodes, *L L'*. This cylindrical cell is supported by the brass arm *M* screwed to the front part of the case. The interior circumferential walls of *G* are lined with paper (not shown in the drawing). The back electrode *L* is secured to the back of the cell *G* by a screw (not shown). The front electrode is carried on a metallic piece, *N*, over which is slipped a mica washer, *O*, of sufficient diameter to completely cover the opening in the cell *G*. The metallic piece *N* terminates in the screw *P*, which passes through the diaphragm *D* and is locked against it by two nuts, *R*. The space in the cell *G* is filled with granules of carbon. When the required amount of granular carbon has been put in the cavity and the front electrode slipped into position, the plate *N* is screwed home, binding the mica washer *O* firmly against the face of the cell *G*, thus firmly confining the granules in place. The electrodes are of somewhat less diameter than the interior of the cell, so there is considerable space around their edges filled with carbon granules, which prevents the binding of the electrodes and allows room between them for the expansion of the granules when heated by the passage of a current. The vibrations of the diaphragm are transmitted directly

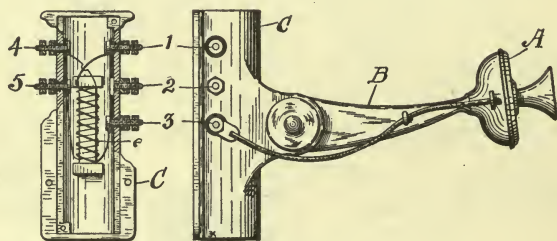


FIG. 22.

to the front electrode, which is allowed to vibrate by the elasticity of the mica washer, while the back electrode is held stationary in the case. The back electrode is mounted on the frame, while the front electrode is connected by an insulated wire to the terminal *S*, which is mounted on an insulating block, *T*, in the manner indicated in the drawing. The terminal *S* is connected by a flexible conductor to binding post 3 on the case *C*. Posts 1 and 2 are the battery posts and 4 and 5 the terminals of the secondary winding of the induction coil. This form of arm mounting and connection is similar in nearly all the transmitters used on the wall instruments employed by the Signal Corps.

SWEDISH TYPE OF TRANSMITTER.

The Swedish type of transmitter is shown in Fig. 23. The transmitter is inclosed in a metal case, *A*, consisting of two parts flanged together, into the front part of which is screwed a metallic or hard-rubber mouthpiece. This case is shouldered on to the hollow cylindrical brass block *B*, which, in its turn, fits into the movable arm *D*, and is fastened to it by the set screw *d*. The metal diaphragm *E*, which serves as a front electrode, is spring-supported against a shoulder in the front part of the case by two double-pointed leaf springs, *F*, which are fastened to the cylindrical portion of the case by the screws *f*.

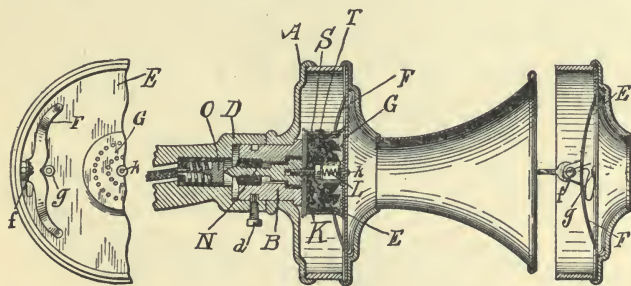


FIG. 23.

One of these screws is connected by a flexible insulated wire to the diaphragm, where it is fastened by the screw *g*. In front of the diaphragm is placed a disk of shellacked silk, which prevents the moisture of the breath from entering the transmitter. A circular metallic disk, *G*, whose inner surface is gold-plated, is fastened to the center of the diaphragm by the screw *k*. The interior surface of this disk is roughed by two concentric rings of hemispherical projection, to give a greater area to the disk for the contact of the carbon granules which are held between it and the carbon block *K* by a cylindrical piece of silk or felt, *S*, which surrounds the block and is secured to it by a rubber band, *T*, or else by the use of fish glue. The carbon block is insulated from the brass piece *B* by sheets of paper. The vibrations of the diaphragm are damped by the coiled spring *L*, located in the chamber in the center of the front face of the carbon block. The spring rests on a tuft of cotton, or felt, and bears on the center of the diaphragm.

The carbon block *K* is fastened by the screw *M* to the brass screw plug *N* that fits into the brass piece *B* and is insulated from it. The end of this screw plug is in contact with the spring-supported plunger *O*, located in an insulated chamber, and the movable arm *D*. The spring is connected by an insulated wire in the usual manner to one side of the primary of the induction coil.

THE GOLD-BUTTON TRANSMITTER.

The gold-button transmitter of the Lambert-Schmidt Telephone Company is shown in Fig. 24. The transmitter is inclosed in a metal case *A*, consisting of two parts flanged together, into which is screwed the hard-rubber mouthpiece. The case is shouldered on the hollow cylindrical brass block *B*, which slips into the transmitter socket of the solid arm, and is held in place by a set screw. The metal diaphragm *C*, whose edge is incased in a soft-rubber ring, *D*, is held in place by two damping springs (not shown in figure) in the same manner as the solid-back transmitter. The outer edge of the cup *E*, which is made of insulating material, is threaded to fit the ring *F* of the same material, which clamps a small aluminum diaphragm *M* over the top of the cup. The back

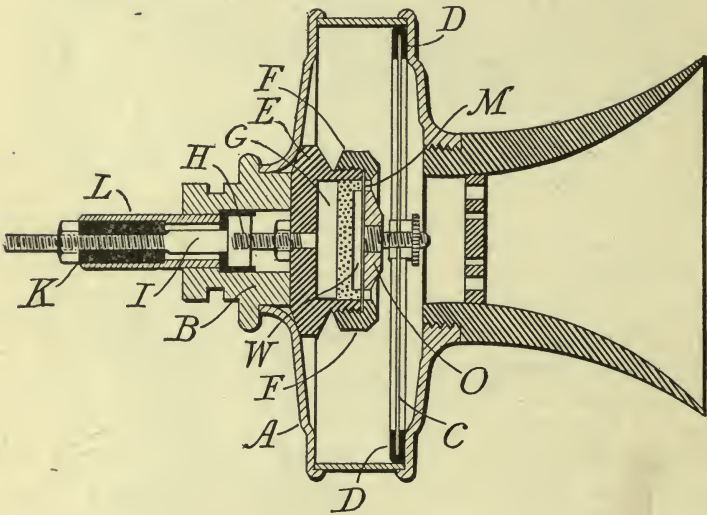
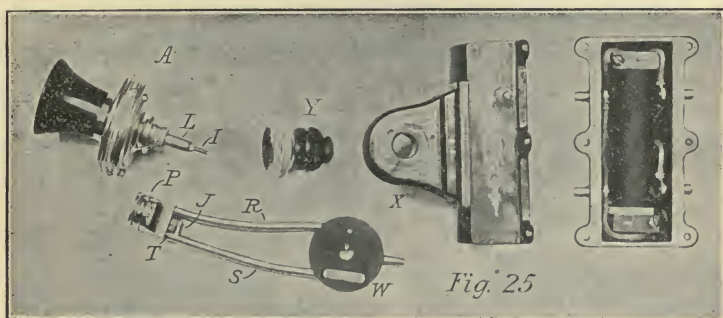


FIG. 24.

electrode *G* is of gold-plated metal. The screw *H*, fastened to the back of the electrode, passes through the cup, holding it in place, and is attached to the standard *I* that is passed through the insulating bushing *K* in the sleeve *L*. *I* is threaded at its end and engages in a hole in the standard *J* (shown in Fig. 25) of the solid arm, and serves as one terminal of the transmitter. The front electrode *N* is also of metal, gold-plated, and is firmly held against the aluminum diaphragm by a clamp nut *O*. The front electrode is connected to the diaphragm *C* by lock nuts in the usual manner and the cup is filled with fine granulated carbon. The standard *I* and the collar *L* form the two terminals of the transmitter.

SOLID ARM FOR TRANSMITTER.

The transmitter above described slips into the transmitter socket *P*, which is attached to two solid arms or rods, *R* and *S*, Fig. 25, and held there by a set screw. *R* is fastened directly to the transmitter socket and *S* passes into and is insulated from it by a hard-rubber bushing, *T*. In the rear of the socket the standard *J* is



fastened to the arm *S* and its top tapped to take the screw thread on the end of *L*. The other ends of the rods are embedded on the opposite sides of the hard-rubber disk *W*, which is pivoted between the cast-iron cheek pieces *X* by the bolt *Y*. On each side of the hard-rubber disk a spring is attached to each of the rods, giving a rubbing contact against the inside of the cheek pieces and permitting the arm to be raised and lowered without breaking contact. The cheek pieces are mounted on hard-rubber foundation plates and connections made to the binding posts on the side of the casting that contains the induction coil.

CHAPTER IV.

BUZZERS.

In the service and field buzzers, which are used for both telegraphy and telephony, the buzzer is simply a coil of low resistance and high self-induction in series with a circuit breaker, a telegraph key, and battery. On opening the circuit the discharge of the coil goes to line, and, owing to its high self-induction and consequently comparatively high electro-motive force of break, enough current reaches the telephone receiver at the other end of the line to give audible signals.

SERVICE BUZZER.

The service buzzer, Fig. 26, is contained in a hard-wood box of cubical form, $8\frac{1}{2}$ inches on the edge, and weighs about 8 pounds. The working parts are fastened to the front, which is hinged, and when in use lowered on a table. The back is also hinged to give access to the cells of dry battery that are contained in the body of the box. The transmitter and receiver fit in the space above the battery. A condenser of one-third microfarad capacity is placed under the board on which the working parts are mounted, and is connected to binding posts 2 and 3. The buzzer coils *E* are simply two coils wound in parallel, eight ohms each, one side of the windings of each coil being grounded on the frame at 8, and the other side connected at 9.

The circuit breaker consists of a thin iron reed, fastened by a screw to the core of the left-hand coil, and supported in the middle by a brass rod, which passes through a vertical standard at 12, and is capable of being adjusted by the two antagonistic lock nuts. There is a particular note for working best adapted to each condition of the line, and this note is obtained by changing the tension of the reed and altering the air gap between the free end of the reed and the core of the right-hand coil. The two contact points at 10 are of platinum, and the pressure of the stationary contact point is regulated by an adjusting screw, which also assists in changing the pitch of the note given by the buzzer. The circuits are shown in Fig. 27. The receiver is attached to 4 and 5, and the transmitter to 6 and 7. The switch *A* short-circuits the contact breaker; the switch *B* changes the connection from telegraph to telephone; switch *C* is used in changing from buzzer to ordinary Morse; switch *D*, when closed, puts one-half battery on the Morse circuit; coil *F* is an ordinary telephone induction coil. When in

use for sending buzzer Morse *A* is open, *B* is on 15, *C* on 25, and *D* open.

For ordinary Morse, *A* is on 12, *B* on 15, *C* on 26, and *D* on 34. For telephoning, *A* is either open or closed, *B* on 14, *C* on 25 or

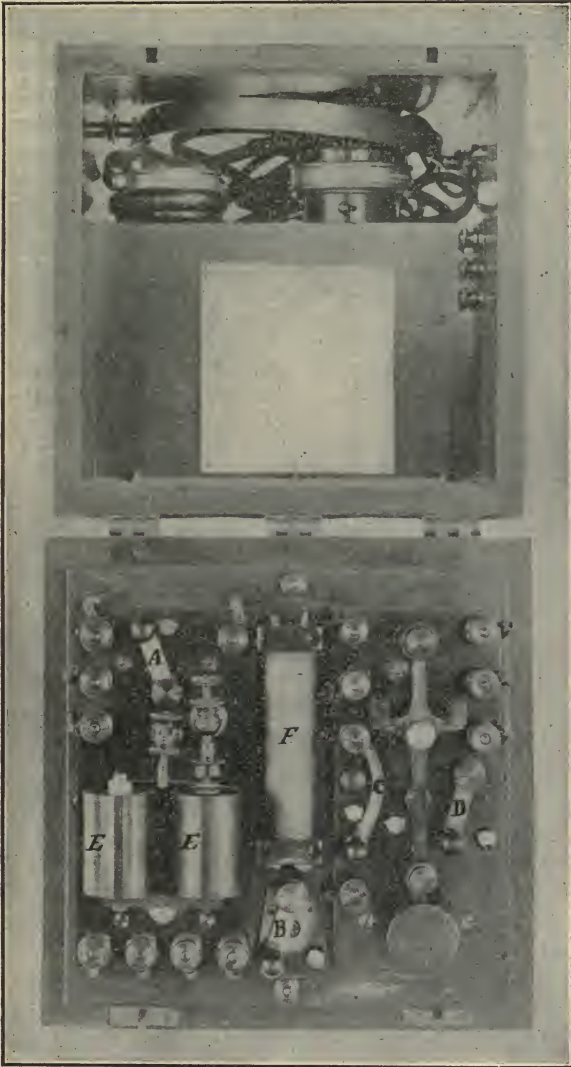


FIG. 26.

26, and *D* open. The battery, which consists of six dry cells, is connected with 30 and 31, the middle of battery with 32. The sending key is the ordinary telegraph key with an additional front contact 35, which is so adjusted that it will barely break when the

key is up. When sending buzzer Morse the current passes through battery, key, and coils to contact breaker, and thence back to battery. Each time the current is broken by vibrations of the reed at the contact points 10, the coils discharge at 8 and 9, and go through 16, and as the key is down to 23 and 29, through key to 35 and 36, and 4 to 2 and line, 1 being earthed. In receiving buzzer Morse the current passes through 2 to 4, through telephone receiver to 5, and back through 15 and 17 and coils to earth. In sending ordinary Morse the current is passing steadily from the battery to 30 and 34, through *D* to 33, to 28, through back contact of key to 29, and through coils as above, no buzz occurring as the vibrator is

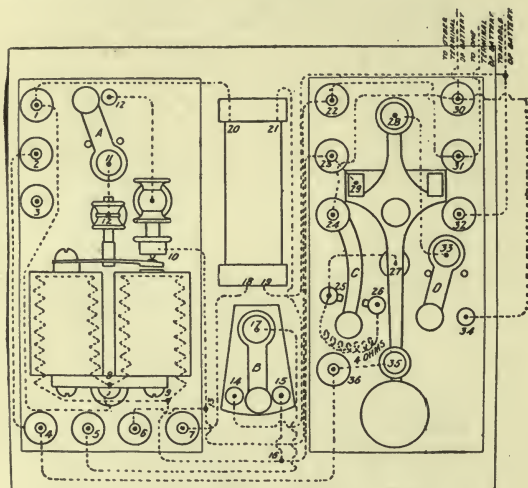


FIG. 27.

short-circuited. When the key is depressed the coils discharge, due to the break occurring at 28. This discharge goes to line as above, and gives a note in the receiver at the distant end. As the key is depressed, contact is made at 27, and current now passes from battery through 30 and 24, through *C* to 26, and through the resistance to 25 and 27, through the key to 29, and through the coils as above. The current is consequently weaker than before, and when the break occurs on the up stroke the sound in the distant receiver is less than on the down stroke; thus giving the same effect as with an ordinary sounder. The telephone circuits are the same as in the ordinary telephone. The condenser is used when it is desired to cut the kit in on a telegraph line.

THE FIELD BUZZER.

The field buzzer, shown in Fig. 28, is a simplification of the service buzzer. The leather containing case is divided by a vertical partition in two parts, one-half containing four cells of

dry battery; the upper part of the other half is covered by a hard-rubber plate, which supports a simple make and break key, circuit

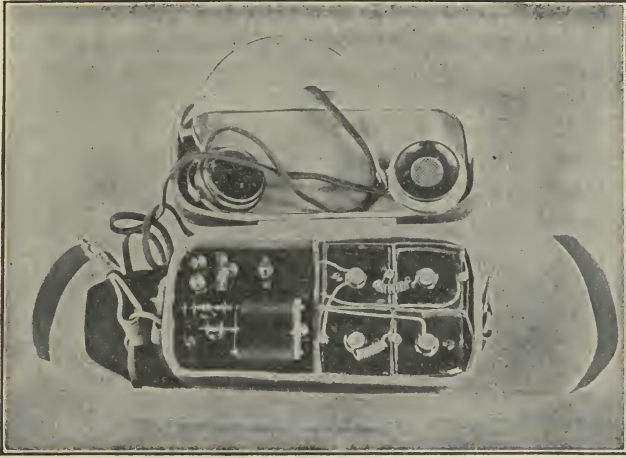


FIG. 28.

breaker, and buzzer coils, together with the line binding posts. Underneath this hard-rubber plate is a pocket for the head receiver

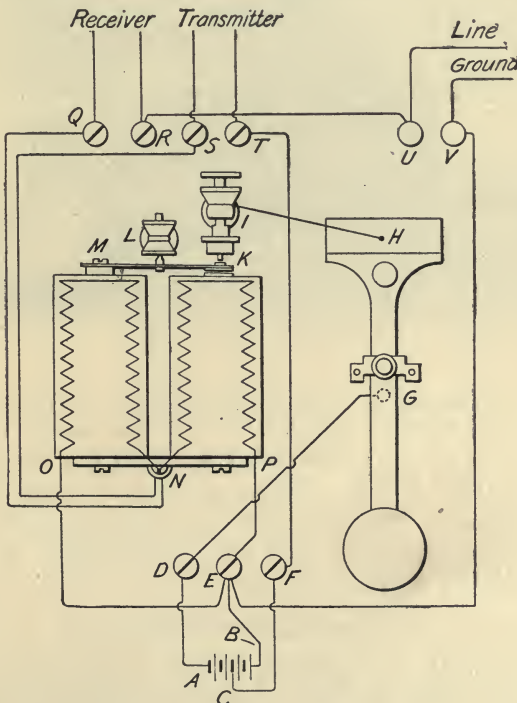


FIG. 29.

and transmitter; this pocket is closed by a leather flap on the side. The wiring of this buzzer is indicated in Fig. 29. When used as a telephone instrument the buzzer serves as a call, and the battery circuit is closed by a switch in the side of the transmitter case. When the receiver is being used it must be held in a vertical position, otherwise the carbon granules may not touch the front electrode of the transmitter.

THE FIELD TELEPHONE.

The field-telephone kit, shown in Fig. 30, is contained in a strong wooden box, which holds the magneto, call bells, combined receiver and transmitter and dry battery. The magneto handle, when in use, passes through a hole in the side of the box and screws on to the driving axle. When not in use the handle is slipped into a wooden block in the top of the box. The combined



FIG. 30.

receiver and transmitter, or microtelephone, consists of a transmitter of the Swedish or gold-button type and watch-case receiver. These are connected together by steel rods for strength, which form part of the circuit and are partially covered by a wooden handle, containing a compression switch for controlling the dry batteries. The circuits in this kit are the same as those in a standard bridging telephone.

THE CUT-IN TELEPHONE.

The cut-in telephone, as shown in Fig. 31, is used for cutting in on an ordinary telegraph line to talk with repair parties without

heard. This is done by inserting a coil of high self-induction between the telegraph instrument and the telephone. This coil so regulates the Morse current with respect to the receiver that when the telephone is joined through a condenser to the line no sound of the telegraph instruments can be heard, but telephonic speech coming over the line will be audible. The condenser, in addition to helping regulate the Morse current, prevents the telegraph line from being grounded through the telephone. The hard-wood box has the transmitter *T* fastened to the back of the door. The rubber mouthpiece of this transmitter when in use is screwed to the front of the door, and when not in service is held by a clip spring on the front of the partition, behind which are located the regulator coil *C* and condenser *K* and the cells of dry battery. The coil *C*, whose core consists of a number of soft-iron wires projecting a couple of inches beyond the ends, is wound to four ohms so that when the serrated metal plate *P* is scratched by the stylus *S*, the discharge current will be of such volume as to produce a loud note in the receiver at the distant station. The push-button switch *B*, on the right-hand side of the box, closes the transmitter circuit when in use. When the two stations that are communicating with each other, are between two telegraph stations, one binding post on the top of each box is connected to the telegraph line and the other grounded. When a telegraph station intervenes between the two telephone stations, the line binding post of the telegraph relay must be bridged by a condenser.

REPEATING COIL.

It is sometimes necessary to connect a grounded line to a metallic line, or a grounded line to a metallic switch board, or vice versa. This is done by using a repeating coil, which is merely a special form of an induction coil. The two windings of this coil have the same number of turns, and are wound to the same resistance. The



FIG. 32-A.

ends of the iron wires of the core are bent over the windings so as to form a closed magnetic circuit around them. The terminals of each of the two windings are brought out to binding posts. The wires of the metallic circuits or leads to the metallic switch board are connected to the two terminals of one of the windings. One terminal of the other winding is connected to the grounded circuit or switch board, and the other terminal of this winding is grounded as indicated in Fig. 32-A.



CHAPTER V.

SWITCH BOARDS.

For a small system of lines, not exceeding one hundred, a switch board of the type similar to that shown in Fig. 33, front view and section, is employed. This board is for metallic circuits and the details of the circuits are shown in Fig. 34. Each line is connected through a jack to its drop; the board is supplied with cords and plugs for making the cross connections between the lines, and with the necessary ringing and listening keys and clearing-out drops for the operator's circuits on the board, together with the operator's set. The board illustrated in Fig. 33 has one

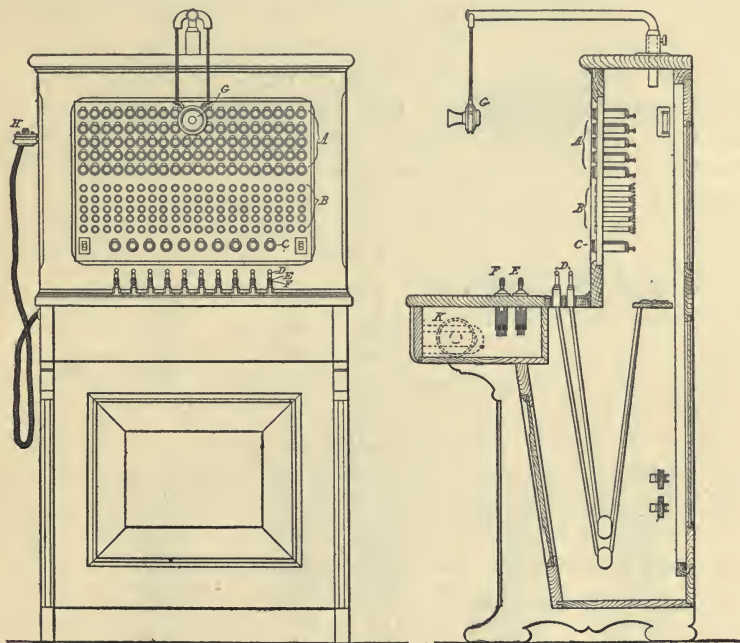


FIG. 33.

hundred line drops, *A*, mounted in a hard-rubber panel contained in the face of the upper part of the cabinet; one hundred jacks, *B*, mounted immediately below the drops, and ten clearing-out drops, *C*, below the jacks. On the shelf which projects beyond the face of the upper part of the board are mounted ten pairs of plugs and cords, *D*; ten listening keys, *E*, and ten ringing keys, *F*; operator's transmitter, *G*, which is adjustably mounted; operator's receiver, *H*, of the head type; magneto, *K*; night-battery circuit switch, *L*, and

the battery for the operator's set, which is not shown in the figure. The cords are kept taut and in position by pulley-suspended weights.

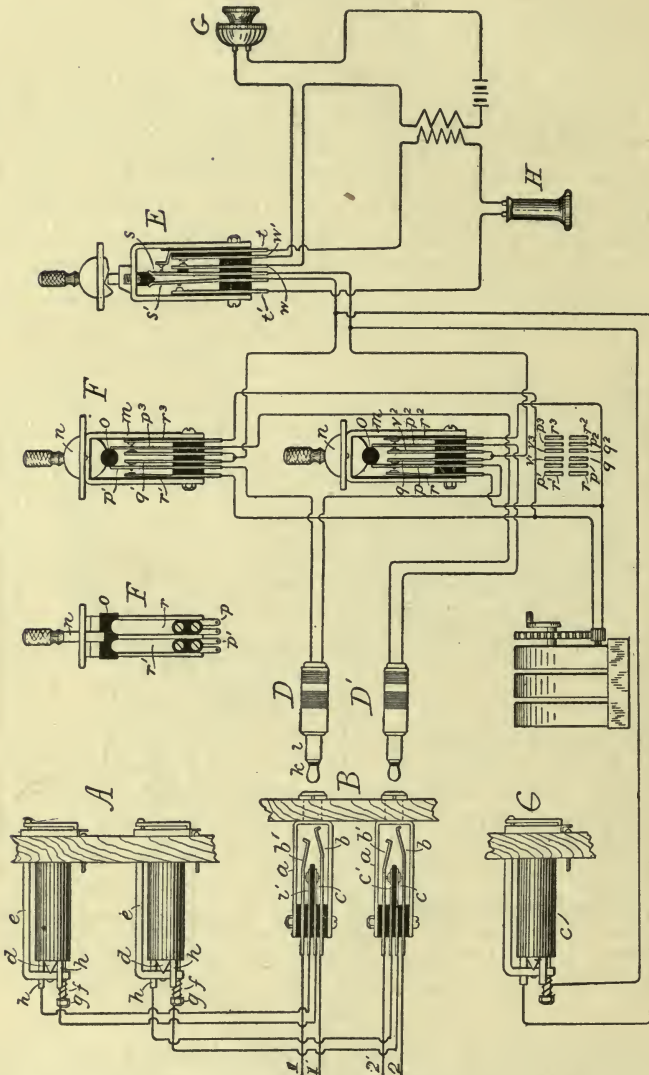


FIG. 34.

METALLIC CIRCUIT BOARD.

To understand how such a board is wired and operated two drops are shown in Fig. 34, together with one set of cords and plugs and their ringing and listening keys, and operator's set. The jack *B*

consists of a punching a that enters a hole bored through the hard-rubber panel and is fastened thereto. The two springs $b\ b'$ and the two leaves $c\ c'$ are fastened in the frame by a nut and screw, which passes through them and the frame; they are separated from each other and the frame by hard-rubber blocks. At the outboard ends of $c\ c'$ are riveted two platinum contacts which touch the springs $b\ b'$ when the jack is closed. The line leads are attached to $b\ b'$ and the leads to the drops A to $c\ c'$, and when the jack is open an incoming ring will pass over b , through the platinum contact to c , through the drop to c' , thence to b' and back to line. The drop consists of an ironclad winding, the back end of the core projecting past the coil, milled to a wedge shape, d , that supports the armature e . The armature is L-shaped, the short arm of the L fitting against the wedge-shaped end of the core, forming a knife-edged pivot, the long arm extending over the coil and pole piece in front of the coil. This pole piece (not shown in the figure) is a strip of iron as wide as the armature and extends upward from the core, leaving a very small distance between the end of the pole piece and the armature. The armature terminates in a catch which projects through the panel and holds the shutter. The coiled spring f , which is carried by a small post, g , bears against the lower end of the short arm and restores the armature when no current is on. The leads from $c\ c'$ pass through two hard-rubber collars, h , to the windings of the ironclad coil. The clearing-out drop C is of the same construction as the line drops, but is wound to a much higher impedance. The cords which are attached to the plugs $D\ D'$ consist of two conductors, the outer one a double steel spiral and the inner one a copper spiral. A double cotton braid insulates the conductors from each other, and the cord has an outer cover of braided linen. The two conductors are connected, one to the tip k and the other to the sleeve l , and when the plug enters the jack the tip k bears against b' and the sleeve l against b . These cords are connected together through the ringing key F , which, for ease of illustration, is represented as cut through the middle, slid apart, and shown in plan, a side view of which being also given. The frame of this key is a punching m , which is fastened to the underneath side of the shelf of the cabinet, the cam lever n projecting through its top. Securely fastened to the bottom of the cam is the hard-rubber cylinder o , which presses against the four long springs, p, p^1, p^2 , and p^3 . Eight other shorter springs are fastened together and to the frame, but insulated from each other, the long springs, and the frame by hard-rubber blocks. At the tops of each of these springs are riveted platinum contacts, and when the cam lever is in its normal or upright position p is in contact with q , p^1 with q^1 , p^2 with q^2 , and p^3 with q^3 . When the

lever is turned forward the springs p and p' are bent over and their contacts touch r and r' ; when turned in the opposite direction p^2 is brought into contact with r^2 and p^3 with r^3 . The two conductors from the cord D are connected to p and p' , the conductors in the cord D' to p^2 and p^3 , r and r^2 being connected to one side of the magneto and r' and r^3 to the other side; q is permanently connected to q^2 and q' to q^3 . Each key of this type serves as a ringing key for the cord circuits that are connected to both the plugs behind it; when it is pushed toward the board it rings the circuit that connects with the plug nearest the board, and when pushed from the board rings the circuit connected with the other plug. When the key is released it returns to its normal or vertical position. The listening key E has a cam of the plunger type, the springs s s' being bridged across the wires that connect q with q^2 and q' and q^3 . Bridged across these wires are the leads from the clearing-out drop C . One terminal of the secondary of the induction coil and one terminal of the receiver are connected with the springs t and t' , and the transmitter and battery circuit is connected to the springs w and w' .

To understand how the board is operated; suppose a ring comes in over the line 1 1', throwing the upper drop; the operator inserts the plug D in the upper jack; turning the listening key down, the circuit is as follows: From 1 through b , through the sleeve l , which is connected to the lower conductor of the upper cord, to p , from p to q , from q to s , from s through the contact to t , from t through the secondary of the induction coil and the receiver to t' , from t' to s' , from s' to q' , from q' through the contact to p' , and from p' back through the tip of the sleeve k to b' of the upper jack and out to line 1'. The battery circuit of the operator's set is closed when the lever of the listening key is down. The operator asks what number is required, and let us suppose the answer is the circuit connected to the leads 2 2'. The other plug, D' , is inserted in the lower jack and the ringing key turned toward it; this will call the instrument connected to that line, and the circuit is as follows: Starting from the line 2 as above through the sleeve of D' to p^2 (the handle of the ringing key being supposed to be turned toward the right), from p^2 to r^2 , around through the magneto to r^3 , from r^3 to p^3 , and from p^3 back through the tip of D' , thence through b' to 2'. As soon as the ring is made the key, being self-restoring, returns to its vertical position, and the two lines are connected together as follows: 1 to 2 and 1' to 2', through the cords, which are connected together at q q^2 and q' q^3 . When the stations are through talking and they ring off, the ring coming through the ringing key and through the clearing-out drop, throwing the drop, indicating that this pair of cords is no longer required, when the operator pulls the cords from the jacks.

GROUNDED CIRCUIT BOARD.

To understand how such a board is wired and operated, two drops, say for lines No. 20 and 68 (each supposed to be a grounded circuit), are shown in Fig. 35, together with one set of cords and plugs with their ringing and listening keys and the operator's set.

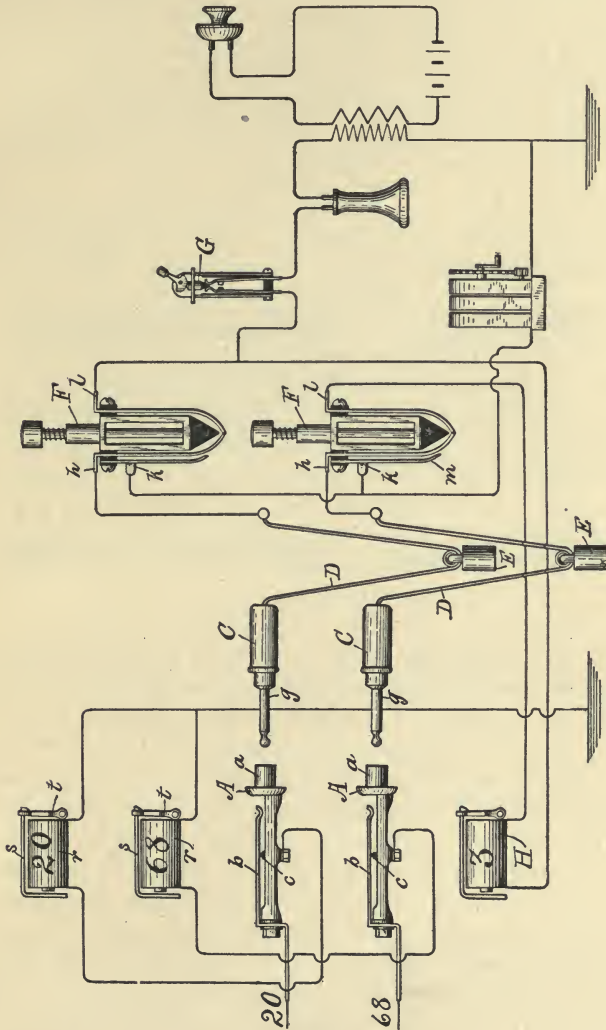


FIG. 35.

The jack *A* consists of a cast piece, in the form indicated, with a projecting shoulder, *a*, which enters a hole bored through the panel and is fastened to it by small screws. The line spring *b* is securely fastened to the body of the jack at its end by a lock nut.

The line lead is soldered to the end of the spring. This spring rests normally on the pin *c*, which passes through the body of the jack and is insulated from it by a hard-rubber bushing. One side of the line drop is connected with the pin *c*, and the other side is grounded. The coil *r* of the line drop is mounted on the rear face of the panel and has a pivoted armature attached to the upper rear portion of the frame (not shown in the drawing). To this armature is attached the bent rod *s*, hooked at its outer end and passing through a hole in the panel. This hook engages the upper edge of the pivoted shutter *t*. When the armature is attracted it raises the hook of the calling line, the shutter falling into a horizontal position, thereby displaying the number of the calling circuit.

A night bell circuit is frequently supplied to each drop, which attracts attention to calls coming in when the operator is not at the board. The circuit contains a bell, battery, and switch, and is closed by the falling of the drop into a horizontal position. This circuit is shown diagrammatically in Figs. 37, 39, 44, and 47. The plug *C* consists of a cylindrical piece of brass, *g*, of such size as to enter the jack *A* and break the connection between the line spring *b* and the pin *c*. Attached to the end of this brass cylinder, which is usually covered by a hard-rubber or fiber handle, is the flexible insulated cord *D*, which is kept stretched by the pulley-supported weight *E*. These cords are arranged in pairs and numbered 1, 2, 3, etc., and are connected to the lug *h* on the same side of the ringing key *F*, while the magneto is connected with the lug *k*. The clearing-out drop *H* is connected to the lug *l*, on the other side, to the ringing keys. One side of the receiver is connected to the clearing-out drop through the listening key *G*, while the other side is grounded through the secondary of the induction coil.

The listening key is sometimes arranged to close the battery in the primary side of the induction coil when the receiver is cut on the cord circuit, but it is more frequently controlled by a separate switch. To understand the operation of the board, suppose a call comes in on line 20. The drop will then fall and display the number 20 to the operator, who thereupon takes, say, the upper plug *C* of, let us say, pair 3, and places it in the jack 20. He then turns down his listening key and ascertains what connection is desired. The circuit will then be through jack 20 with its plug and cord, through the upper ringing key, through the listening key, receiver, and secondary to ground. Let us suppose that the circuit asked for is No. 68. The operator will then place the lower plug of pair 3 in jack 68, and pushing down the lower ringing key turns his magneto, which calls the instrument 68. The ringing circuit in

this case will be from the magneto to the lug *k* on the lower key, and as the key is depressed the spring *h* will be in contact with the strip *m*, to which the lug *k* is soldered. Thence through the cord, plug, and jack to line 68. When the operator releases the ringing key, 68 and 20 are connected and can talk. The circuit is through the jacks, plugs, cords, ringing keys, and clearing-out drop. When conversation has been finished and the stations ring off, the shutter of clearing-out drop 3 falls, and so informs the operator that the lines connected by this pair of cords are no longer needed. He then removes the plugs and restores the clearing-out drop.

MONITOR SET.

A very small compact board which can be used for systems not exceeding ten lines is shown in Fig. 36. This is the monitor set of the American Bell Company and is entirely without cords.

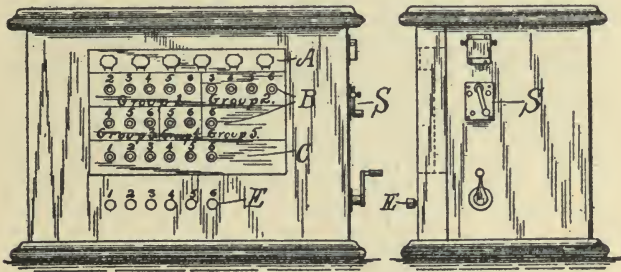


FIG. 36.

The board shown in this figure is wired for six lines. A hard-rubber panel contains six drops, *A*, and the connecting jacks for the various groups, *B*. Below these jacks is a line of listening jacks, *C*, and below this, passing through the front of the board, is a set of ringing keys, *E*. This board is supplied with a magneto, usually a desk set for the operator, a night-bell circuit and switch, and a number of plugs. A common battery is used both for the transmitter and night-bell circuits. The wiring of the board is shown in Fig. 37.

The incoming lines pass through the ringing keys, which have the magneto bridged across them, as usual. Just inside the ringing keys each line is bridged with a listening jack, the line leads going to the frame and second spring in each jack, while the operator's set is bridged on the first and third springs. Inside of these connections the drops are bridged and serve both for calling and clearing out. Each drop is attached to the night-bell circuit, which is controlled by the single-point switch, *S*. Each line is then brought to the frame and second spring of all the jacks in its

own group, while the other line leads are brought in succession to the first and third springs of its appropriate jack.

For example, in group 1 there are five connecting jacks, one for each of the lines 2, 3, 4, 5, and 6. The plug that is used in the

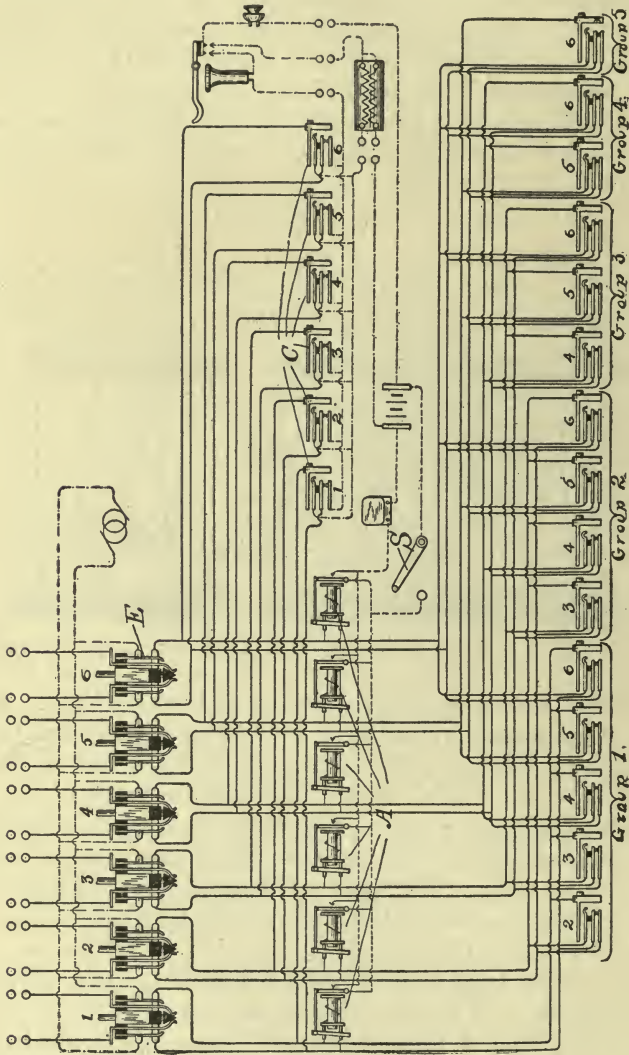


FIG. 37.

jacks is simply a solid-metal cylinder, and, by pushing it home in the jack, connects the frame to the first spring and the third and fourth springs together. By placing a plug in any jack of a section, the line to which it belongs is connected to the line whose

number is on the face of the jack. In group 2 are found lines 3, 4, 5, and 6. In group 3, lines 4, 5, and 6, etc.

The operation of this board is very simple. When a call is received the operator plugs his instrument in by inserting a plug in the listening jack corresponding to the calling line. When notified as to the line desired, he rings it up by depressing the ringing key corresponding to the line called for and then places a plug in the section of the calling line in the jack of the line called

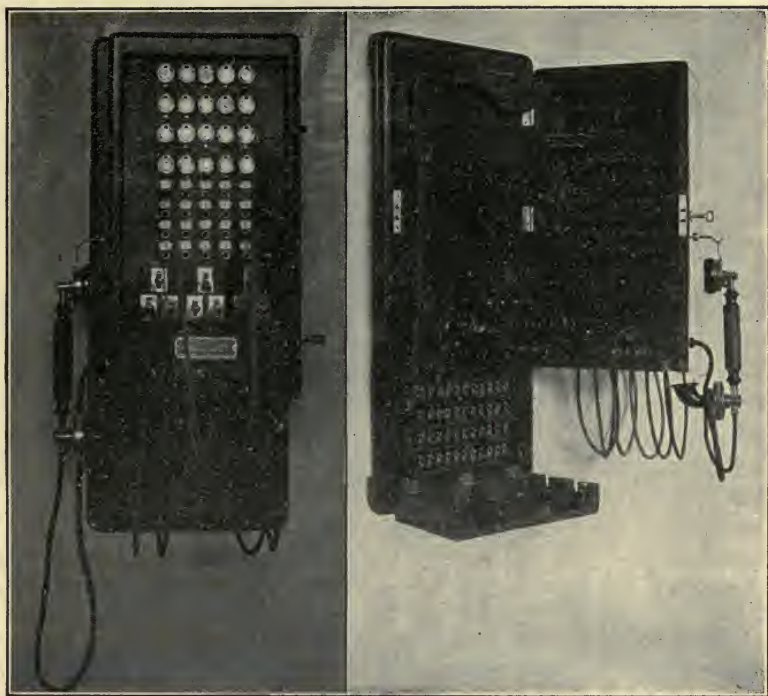


FIG. 38.

for. For example, suppose line 2 calls. The operator places a plug in the listening jack 2, row *C*, and is informed that No. 6 is wanted. He depresses the ringing key 6 and after turning his magneto inserts a plug in No. 6 jack in group 2, removing his own listening plug. When 2 and 6 are through and they ring off, both drops, 2 and 6, will fall. They are then restored and the plug in group 2 is withdrawn.

WALL CABINET SWITCH BOARD.

The wall cabinet switch board, as shown in Fig. 38, is designed for small exchanges, from 20 to 40 lines, where it is desired to save space, and is especially adapted for installation in fortifications.

The working parts are mounted on a hard-rubber panel in the front of the box, which is fastened with strong hinges to the back-board. In the 20-drop board, illustrated in the Fig. 38, three pairs of plugs and cords are used, and in the 40-drop board six. The jacks are located immediately below the drops. The upper row of keys serve as listening keys for the pair of cords below them, while the ringing keys are located just below the listening keys, each one above its own cord. A microtelephone is used for the operator's

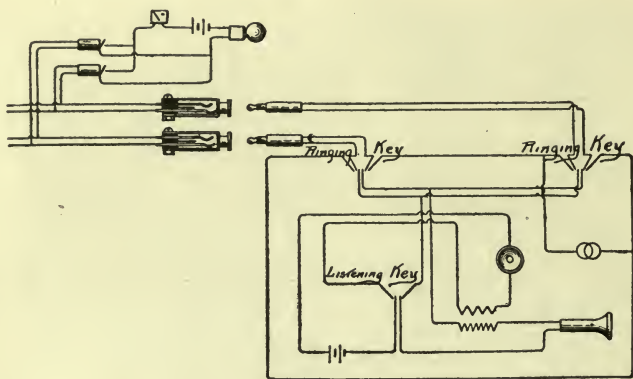


FIG. 39.

set, and the drops are supplied with a night-bell circuit. The wiring of this board is shown in Fig. 39.

CORDLESS BOARDS.

For field use the switch board must be compact and strongly built so as to stand shocks in transportation and actual service, and the cordless boards of the Signal Corps are designed with these ends in view.

1902 Model.—A front view and section of this model is shown in Fig. 40. This board has neither jacks nor cords. The working parts are contained in a strong wooden case, *A*; the front and back being closed by strongly hinged doors, *B* and *C*. A partition, *E*, is inserted in the front of the box, in the upper part of which is the hard-rubber panel *F*. This hard-rubber panel contains ten line drops, *G*, of the same construction as those described in the metallic switch board. Immediately below this line of drops are inserted two metal strips, *H* and *I*, that contain the keys for ringing and making the necessary connections between the line circuits. Below the panel is inserted a small strip, *K*, holding three listening keys, and below this is the key *L* that closes the night battery circuit. The magneto *M*, dry battery *N*, and induction coil *O* are securely fastened in the box behind the partition *E*. In a recess in the

bottom of the box is the combined receiver and transmitter *P*. On the top is a row of binding posts, *Q*, which serve as the line terminals, and are protected by a hinged cover, *R*. The box is carried by the strap *S*, which passes over the top and is fastened to the

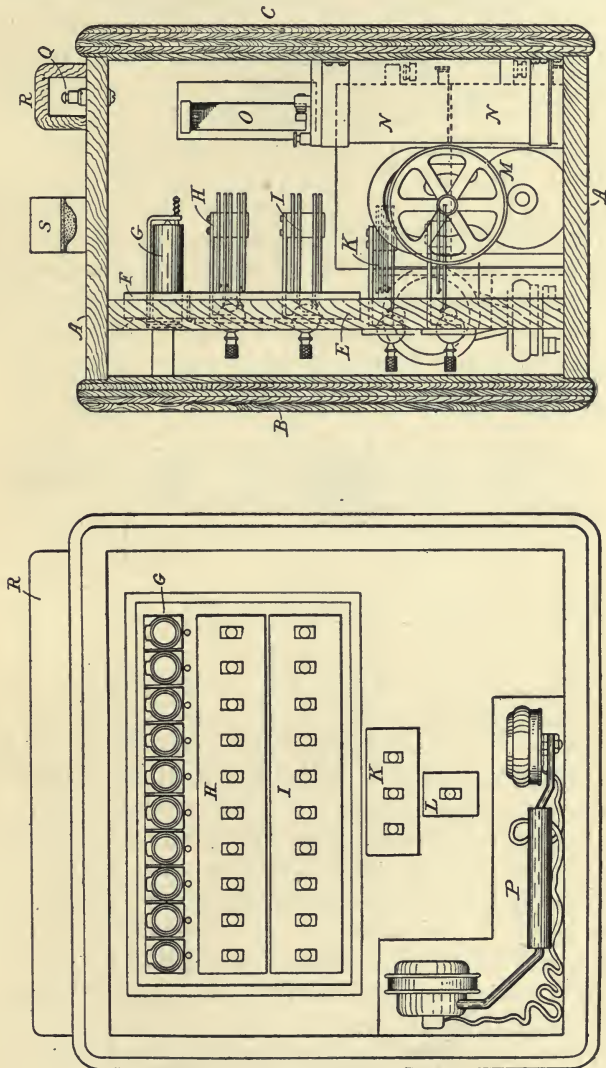


FIG. 40.

sides. The line drops *G* are bridged across the leads connecting the binding posts *Q* with the line of keys *H*. The details of these keys will be described later. The keys in the rows *H* and *I* are normally in a horizontal position, but can be turned either up or

down. When the keys in the row *H* are turned up they serve as ringing keys for the lines immediately above them. When any two keys of the row *H* are turned down they cross connect their corresponding lines. The keys in the row *I* when turned up or down cross connect the lines corresponding to them. The keys in the row *H* are combined ringing and cross connecting keys and the keys in the row *I* are cross-connecting keys. The left-hand key of the row *K* serves as a listening key for the lines cross-connected by the down position of the keys in row *H*; the middle for the up position in the row *I* and the right hand one for the down position of *I*. The key *L* serves to put the night-bell circuit on the drops. As there are practically three rows of cross-connecting keys, six of the ten circuits can be used simultaneously. To illustrate how the board is operated: When an incoming ring releases the shutter of its drop (if the row *H* is used) the corresponding key in that row is first turned down and then the left-hand listening key is turned down. When the station which the calling station

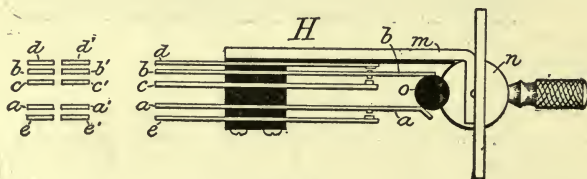


FIG. 41.

desires to communicate with is ascertained, the key in the row *H* corresponding to the desired line is turned up and the generator revolved. This will then call the line desired. As soon as the call is made the key is then turned down and the two lines are cross connected. As there is no clearing-out drop when a conversation is finished the ring off will throw both drops, when the connecting keys are then returned to their normal position. Using the row *I*; any two lines are cross-connected by turning their corresponding keys in the same direction, remembering that the middle listening key corresponds to the up position and the right-hand one to the down position in *I*. The combined ringing and listening key *H* is shown in section and plan in Figs. 41 and 44. It consists of a frame, *m*, which is fastened to the metal plate of the row *H*; passing through this plate is the cam lever *n*, which has at its bottom the hard-rubber cylinder *o* that bears against the four long springs, *a*, *a'*, *b*, and *b'*. There are six other shorter springs, *c*, *c'*, *d*, *d'*, *e*, and *e'*, that are fastened together and to the frame by screws, but insulated from each other and the frame by hard-rubber blocks. The springs *a* and *a'* have riveted platinum contacts on their lower sides, while the springs *b* and *b'* have riveted platinum contacts on both sides. The springs *c* and *c'* have platinum contacts on their

upper sides, and when the key is in the normal or horizontal position the contacts on b and b' touch those on c and c' ; d , d' , e , and e' , also have platinum contacts which are open when the lever is in its normal position. The spring a is permanently connected to b and

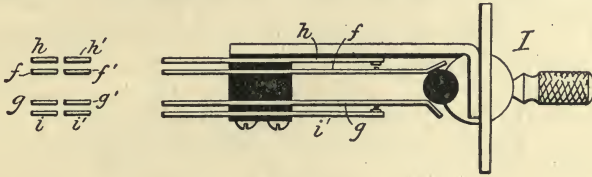


FIG. 42.

a' to b' . The line leads are connected to a and a' , and the magneto bridged across e e' . All the springs d are bridged together, as are also the springs d' , making the first cross-connecting row. A cross-

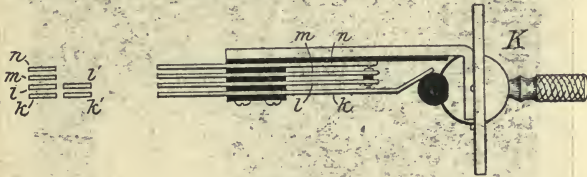


FIG. 43.

connecting key of the row I is shown in plan and section in Figs. 42 and 44, and is of the same general type as the key above described, with the exception that it has eight instead of ten

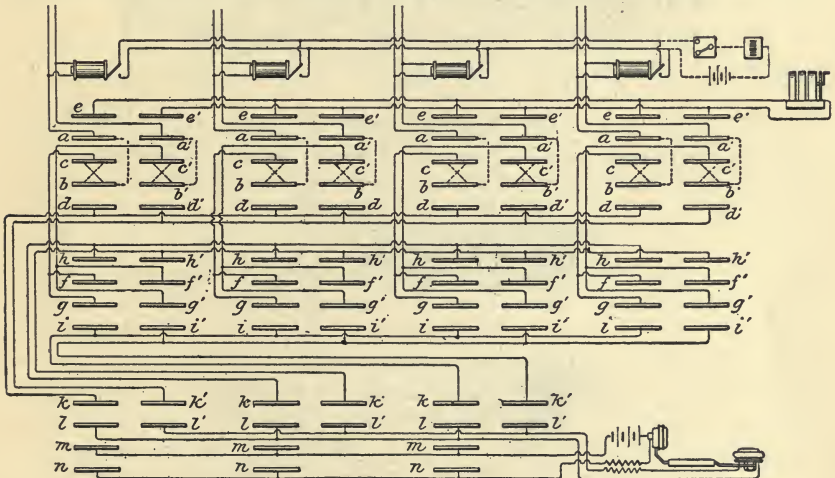


FIG. 44.

springs. These springs are supplied with platinum contacts that are all normally open. The springs c of each key in Fig. 41 are connected to both f and g of Fig. 42 and c' with f' and g' . The springs h are bridged together, as are h' , i , and i' , the line h h'

making the second cross-connecting row and i and i' the third cross-connecting row. The construction of the listening key K is plainly indicated in Fig. 43. The first cross-connecting strip is connected with the springs k and k' of the left-hand listening key; the second cross-connecting row to similar springs of the middle listening key, and the third cross-connecting row to the corresponding springs in the right-hand listening key. The receiver circuit is bridged across the springs l and l' , and the battery circuit across the springs m and n . When the lever of the listening key is in the normal position all the contacts are open. The wiring of the board is shown in plan in Fig. 44, where the keys for four lines are shown.

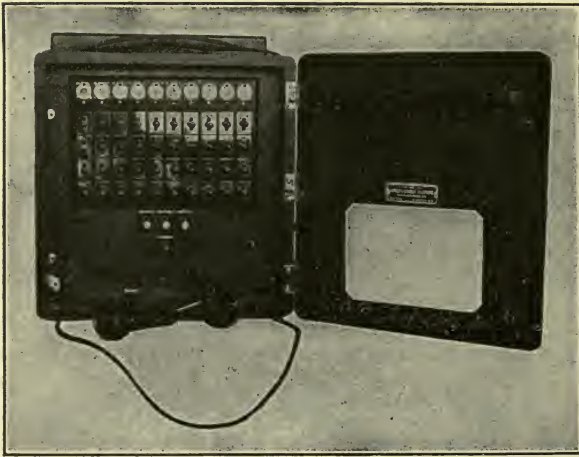


FIG. 45.

1901 Model.—The 1901 model is shown in Fig. 45, and is of the same general construction as the one above described, the difference

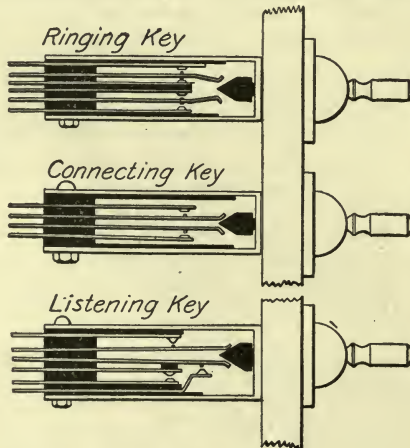


FIG. 46.

consisting in the rows of ringing and cross-connecting keys. There are four rows of keys, the upper row being the ringing keys and the other three rows cross-connecting keys. The method of operation of the board is similar to that of the 1902 model, the only difference being in the fact that the first row of keys in the 1902 model corresponds to the two upper rows in the 1901 model,

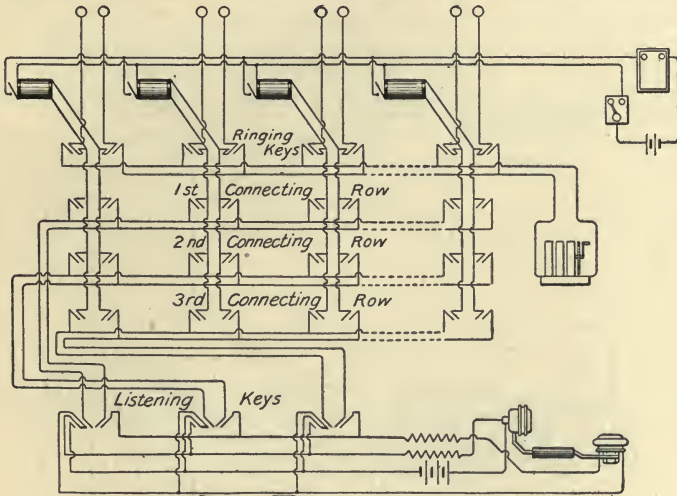


FIG. 47.

and the second row in the 1902 model to the third and fourth rows in the 1901 model. The keys of the 1901 model are different in construction, and a section of a ringing, cross-connecting, and listening key is shown in Fig. 46, while the circuits are indicated in Fig. 47.

INTERCOMMUNICATING SYSTEMS.

In installations where the total number of instruments does not exceed a dozen or so, there is not sufficient business to warrant the employment of a central-station operator, and yet it is necessary that any one of the dozen stations should be able to call any other one at will, especially when all the instruments are in one building. To supply this need intercommunicating systems have been devised. In the usual type of intercommunicating systems there are as many line wires as instruments, plus one common return. All of these wires are connected to every instrument in the system, and the calling of any desired station from any other is done by a selective method of using the circuits.

ERICSSON TELEPHONE COMPANY.

One such system is illustrated in Fig. 48, and is made by the Ericsson Telephone Company. In this plate four sets of instruments are shown, two wall and two desk sets, together with the

corresponding portion of the twelve circuits. It will be observed that each set is provided with a twelve-point switch, one point for every line circuit, and each set, of course, has one particular number, which is called the home number. The operation of this system is very simple if the following rules are observed, but fails completely if they are disregarded. The rules are:

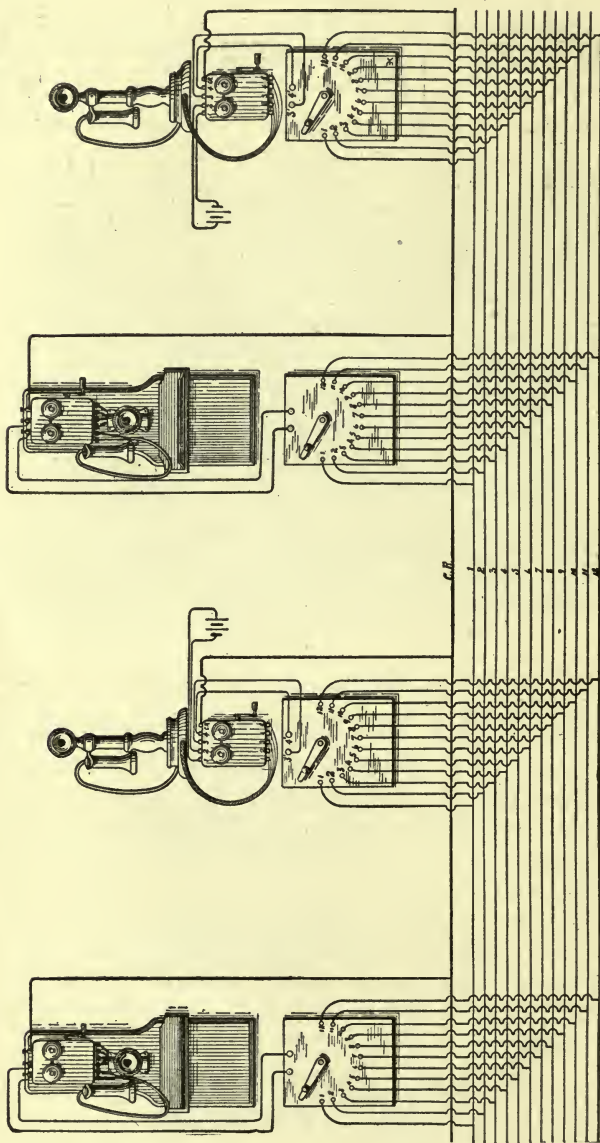


FIG. 48.

1. When your instrument is not in use *always* keep your switch on the home number.

2. When you wish to call any station place your switch on the number of that station.

3. When called by another station *do not touch* your switch.

Suppose, for example, the switches of all the instruments are on their respective home numbers and station 1 wishes to call station 4. He simply places his switch on No. 4 and rings, which calls station 4, while the other stations are not called. It will be seen that the conversation is carried on over line No. 4 and the common return C. R. Had 4 called station 1, the line wire No. 1 and the common return would have been used. This is all there is of the normal operation of the system, but suppose the person at station No. 1 had forgotten to put his switch back on his home number after finishing his conversation with station 4, and had left it on No. 4 point. Then if any other station should wish to call station 1, it could not do so, and in calling station 4, it would also call station 1. Thus the system would be completely deranged so far as stations 1 and 4 are concerned. If any station that has been called afterward moves its switch, it of course cuts itself out of circuit.

LAMBERT-SCHMIDT TELEPHONE COMPANY.

Fig. 49 shows another intercommunicating system on this principle, made by the Lambert-Schmidt Telephone Company. The chief difference is, that instead of a multi-point switch, there is a small plug switch board with each instrument.

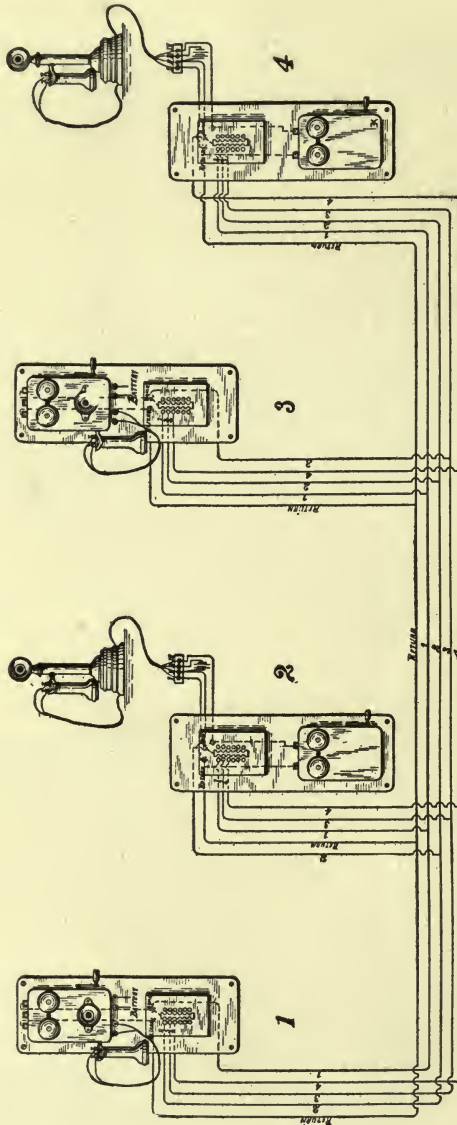


FIG. 49.

CHAPTER VI.

LOCATION AND ELIMINATION OF TROUBLE IN TELEPHONES AND SWITCH BOARDS.

When a telephone is installed it should be fastened against a solid wall so that the ordinary vibration of the building will not affect it, and placed in such a position as to be easily accessible, and not to interfere with free transit around the room, at such a height from the floor so that those who use it can speak into the transmitter without undue stretching or stooping. A brick and plaster wall should be plugged with four tapered wooden plugs about 3 inches long and 1 inch in diameter at the thick end, driven flush with the wall to receive the screws that pass through the four corners of the backboard. The outside wiring should be run as near as possible to where the telephone is located so that the interior wiring may be short. The interior wiring is of inside twisted pair, with the best quality of rubber insulation. Wooden cleats or covered staples must be used in order not to cut the insulation. The leading-in wires must be soldered to the line wires. In passing through a window or door frame, if exposed to the weather, the hole should have a downward slant from the inside so as to prevent the entrance of water.

LOCATING FAULTS.

Experience is the best guide in discovering faults or locating troubles in telephone instruments or in switch boards, and consequently general suggestions only are given. A thorough understanding of the wiring of the telephones and switch boards issued is presupposed. The inspector should be supplied with a key for the magneto box, a small screw-driver, a pair of pliers, an extra receiver, a couple of cells of dry battery, a piece of chamois skin, some moderately fine emery cloth, and two testing cords, which can be conveniently made by soldering spring clips to the ends of a piece of insulated wire of suitable length. The ordinary spring clips in a sleeve supporter or garter will serve and can be obtained anywhere.

It is supposed that the line has been tested and trouble has been located either in an instrument or in a switch board, and the suggestions given are divided into two classes, those for locating faults in the telephone instruments and those which refer to the switch board.

The connections in any telephone must be made with the greatest care and should be so arranged that there is no possibility of any

of the wires coming into accidental contact. No acid should be used in soldering any of the joints. Where it is necessary to make connections under the head of a screw that passes through the box, such an arrangement must be made as to prevent the loosening of the connection by the shrinkage of the wood. Wherever practicable, all connections must be soldered, otherwise spring washers can be supplied. Cleanliness of all parts of the instrument is absolutely necessary for the successful working of the telephone, and whenever an instrument is inspected it should be cleaned up. Loose connections, breaks in the receiver cord, and defective battery are the principal sources of trouble in the instrument, and can be readily discovered. The continuity of any circuit can be ascertained by the use of the extra receiver and testing cords by joining the suspected circuit in series with the receiver and battery. If, on opening or closing the circuit, a click is heard in the testing receiver, the circuit is probably continuous, unless a cut out, as it is called, exists. A cut-out usually occurs in a cord, and is due to the fact that the ends of the broken conductor touch each other and sometimes are separated. It can be discovered by closing the test circuit and shaking the cord. If a succession of clicks is heard in the instrument it is to be inferred at once that it is due to the ends of the broken conductor touching each other and falling apart.

TELEPHONE.

The usual faults in an instrument are developed under the following conditions: First, the station can not ring; second, the station can ring, but speech can not be heard in either direction; third, the station can hear, but can not be heard.

In the first case the fault is in the call box or on the line; in the second case the speaking circuit is either short-circuited or open-circuited; in the third case the fault is in the primary circuit of the transmitter, and may be due to the battery, bad contact in the hook switch, a break or short circuit in the primary, or a short circuit in the secondary coil, or else to a broken transmitter. When the station can not ring, first disconnect the instrument from the line and short-circuit the line posts by a piece of wire. If the instrument is of the series type the bell should ring, and if of the parallel type the bell should not ring and the handle turn with difficulty. If this occurs the fault is not in the magneto itself, but must exist on the line. If in the magneto, look first to see whether the joint connecting the two magnet coils of the bells is not loose, or whether the soldered joint at the hook switch is tight. These two joints are always soldered with rosin. If the joint is improperly made the wires frequently become loose. Test all parts of the circuit for continuity, and see that the automatic shunt is in proper

condition. Inspect the pivots and armature of the bell, and see that the armature is at a proper distance from the cores. It is better to adjust the bell by getting the armature at the proper distance from the cores rather than to change the relative position of the bells on their base. The coiled spring in the shaft of the Western Electric type of magneto is sometimes found broken, and the short circuit is not removed from the armature when the handle is turned.

If the speech can not be heard in either direction, first test the receiver cords for continuity, and then see if the secondary coil is open. If the distant station can hear you, but you can not hear it, the receiver is probably out of adjustment. The adjustment of the receiver can be easily tested by unscrewing the ear piece and then holding the receiver in one hand and tapping it against the other lightly. The diaphragm should slide partially off. If it does not start it is either buckled or else too near the magnets. If it falls off it is too far away from the magnets. The receivers are always adjusted before issuing to the service, and their adjustment should not be altered until the inspector is satisfied that the trouble is entirely due to the adjustment of the receiver. In screwing up the ear piece on the body of the receiver care should be taken that it is not screwed home too violently, as it will sometimes force the diaphragm down against the magnets, or jam it so that it will lose its natural elasticity. In case speech is heard from the distant station, but it reports that it can not hear the home station, the trouble is in the primary side of the talking circuit. The battery should be examined first, and, as a general rule, whenever trouble develops in the talking circuit, examine the battery before making any other test. If the battery is in good working condition, examine the back contacts of the hook arm, and see that they close when the switch is up; then test the continuity of the primary coil; then examine the transmitter.

A vast amount of annoyance will be saved by frequent and careful examination of all screw connections, as there is a constant tendency for them to work loose, even if fastened by lock nuts. As a very large proportion of trouble is caused by loose connections it is always safe to first examine all connections before looking elsewhere for the trouble. A bad ground is likewise the frequent cause of a weak ringing of the bells or faint talking. The ground plate must be in contact with damp earth; it is not sufficient to put the ground plate a few feet under the surface of the earth where, in summer, the ground dries out and, in winter, the earth freezes around and below it. Where both gas and water pipes can be reached the ground wire must be soldered to the water pipe. If none is available a gas pipe can be used, and the wire connected

with the service pipe, outside the meter, otherwise when the meter is removed for repairs or other causes the line will be opened. The telephone must not be grounded on the same conductor that serves for a telegraph ground.

SUMMARY OF FAULTS.

- (a) Station can not ring:
Broken wire in box; the ground wire open; the coiled spring on driving shaft broken.
- (b) Station rings distant station, but its own bell remains silent:
Bad connections in box, or bells out of adjustment.
- (c) Station rings other bells strongly, but its own bells weak:
The ringer magnet is weak, or bells out of adjustment.
- (d) Station rings other bells feebly, but receives incoming ring strong:
Magneto weak, bad connections in magneto, or armature partially short-circuited.
- (e) Station rings and receives ring, but can not talk:
Receiver cord broken, bad connections in box, lever arm does not close, poor battery, open circuit in transmitter or induction coil, bad connections in transmitter arm or small retaining diaphragm of transmitter broken and carbon lost.
- (f) Station rings frequently without apparent cause:
Swinging cross with telegraph or other exterior lines.
- (g) Receiver weak:
Coil partially short-circuited, poor connections, diaphragm bent or dirty. (Diaphragm should be 0.015 inches from the ends of the pole pieces.)
- (h) Home station can hear, but can not talk:
Transmitter circuit open or else short-circuited.
- (i) Home station receives speech strong, but its own talk is weak:
Transmitter packed, damping springs clamp diaphragm too tightly, or batteries run down.
- (j) Speech at distant station is indistinct, a scratching or grating noise:
Loose connections, or battery too strong.

When the inspector is satisfied that the battery is strong, a quick test, which will disclose whether the trouble is on the line or in the instrument, can be made as follows: Disconnect the instrument from the line and short-circuit its terminals; place the ear piece of the receiver in the mouthpiece of the transmitter, and if a singing note is heard the talking circuits are clear. If the magneto rings in the case of a series instrument, or, in the case of a

bridged instrument when the short circuit is removed, the ringing circuit is clear, and the trouble, if any, must exist in the line.

SWITCH BOARD.

In cord switch boards, if the drop does not fall, test first for continuity of circuit, and then see if the pivots are loose. If the pivots are loose, the armature will frequently stick and fail to release the shutter. With a grounded board too great care can not be paid to the ground connections. If, when a ring comes in, more than one drop falls, it may be due to a cross in the lines just outside of the board, or else on the lightning strip, as it is known, to which these lines are connected. This can be readily cleared by inspection. Or else the trouble may be due to the fact that the contacts on the magneto side of some one of the ringing keys are not broken when the key is in a normal position.

When it is discovered that a pair of cords do not perform their proper function, they should be tested for an open or for a cut-out. Cross talk between circuits may be due to the fact that the listening keys do not break the contacts, or else to a cross on the lightning strip, caused by allowing ends of wire to project over and touch adjacent circuits. Whenever cross talk develops the operator of the switch board should notice the pair, or pairs, of cords in which this occurs, and the cause will probably be found due to the fact that the contacts of the listening key do not break when it is opened.

A frequent cause of trouble in the jacks is due to the fact that persons will stick pens or pins in them and break off the points, short-circuiting the springs. The only way to discover this is by thorough inspection of the jacks. To see whether the contacts in the ringing and listening keys break in the proper manner, the part of the board containing them should be placed between the light and the eye of the inspector. By looking at the keys against the light and opening and closing them, it will be discovered whether the contacts break properly or not. Trouble may very frequently be removed from the cord circuit by cleaning the tip and sleeve of the plug with emery paper. When a switch board is new and first placed in service, very frequently particles of metal are found in the jacks and the board can be cleaned by using a hand bellows and blowing out all of the jacks thoroughly. A simple jack cleaner can be made by taking a piece of flexible thin corrugated sheet metal, cutting it to such a size as will enter the jack when open. Thrusting this in the jack and turning it around will remove all foreign particles. It may sometimes happen that the screws holding the insulating blocks in the ringing and listening keys project far enough to short-circuit the adjacent springs.

This trouble can be removed by filing the end down and using a new washer.

The location of trouble in cordless boards is more difficult, as each part of the various circuits will probably have to be tested out in succession before the trouble is located.

BATTERY.

Cracked cells, allowing the solution to run out; loose, dirty, or corroded terminals; loose connections on zinc and carbon; zinc rod used up, or solution too low, are the usual defects in the battery. The jars should be kept filled between the water lines marked on the cells; the tops kept thoroughly clean and free from salts, and the solution up to its proper strength. The necessary directions for setting up the cell and preparing the battery fluid are to be found on the printed label attached to the cell.

CHAPTER VII.

INDUCTIVE AND OTHER DISTURBANCES IN TELEPHONE CIRCUITS.

Almost all the disturbances in an electrically-continuous telephone circuit can be attributed to one of the following causes: Defective connections, electro-magnetic induction, electrostatic induction, and leakage.

DEFECTIVE CONNECTIONS.

Defective connections produce a grating sound, frequently accompanied by a momentary loss of connection, and render the circuit noisy. Bad connections or contacts are usually the cause of trouble in a telephone line in which the difficulty is confined to one instrument alone, or in which the noise continues, all other sources of disturbance being absent.

ELECTRO-MAGNETIC INDUCTION.

Whenever a current flows in a wire it establishes a magnetic field around the wire, in which the lines of force are closed circles in planes perpendicular to the wire, as indicated in Fig. 50.

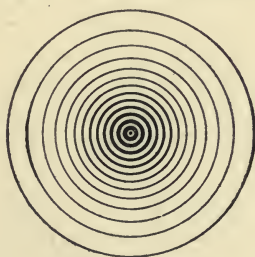
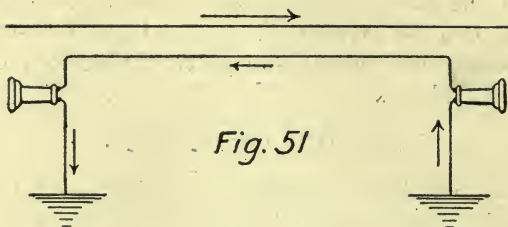


Fig. 50

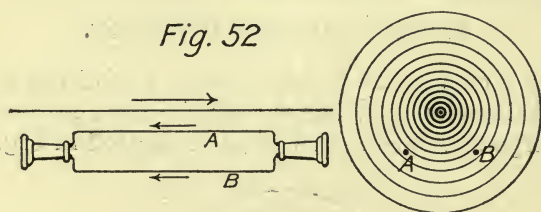
This figure gives a cross section of the wire, shaded, and the surrounding closed lines of force. The intensity of this field of force depends on the strength of the current in the wire. At any point outside of the wire it varies inversely with the distance of the point from the wire. If the current in the wire changes, the entire field of force will vary with the current. If a telephone circuit is sufficiently near a wire carrying a varying current so that the varying magnetic field cuts across the telephone circuit, it will produce an induced current that causes a noise in the receiver connected to the line. The amount of electro-magnetic inductive disturbance depends upon the amount of variation and

the intensity of the disturbing current, the distance that the disturbing wire parallels the telephone circuit, and the relative electrical condition of its two sides.

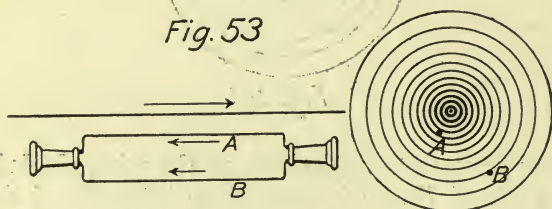
If a conductor carrying a varying current runs near a grounded telephone circuit, as shown in Fig. 51, the field of force cutting



the circuit will produce an induced current, which affects both receivers. If the conductor parallels a metallic circuit, as in Fig. 52, and is equidistant from both sides, the current induced in the



one side will neutralize that in the other at the receivers, as the currents are of the same intensity and flow in the same direction. But if the disturbing wire is nearer one side, as in A, Fig. 53,



than the other side, B, the induced current in A will be greater than that in B, they will not neutralize each other at the receivers, and a noise will result.

TRANSPPOSITION FOR ELECTRO-MAGNETIC INDUCTION.

Should the sides of a metallic circuit be out of electrical balance, the induced current in each will not be the same, and the circuit will be noisy. A complete annulment of the electro-magnetic

induction will be obtained by a simple transposition in the center of the metallic circuit, as shown in Fig. 54, provided the disturb-

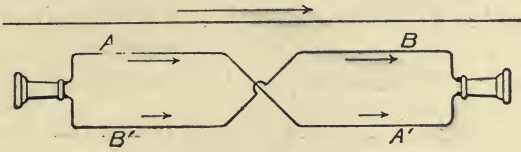


Fig. 54

ing wire parallels the metallic circuit and carries the same current throughout its entire length, because *A* and *A'* are at the same average distance as *B* and *B'* from the distributing wire.

ELECTROSTATIC INDUCTION.

Whenever a charge of electricity exists in a conductor it will induce in all conductors in its vicinity a bound static charge of opposite sign on the sides of the neighboring conductors nearest it, and a free charge of the same sign on the sides farthest away.

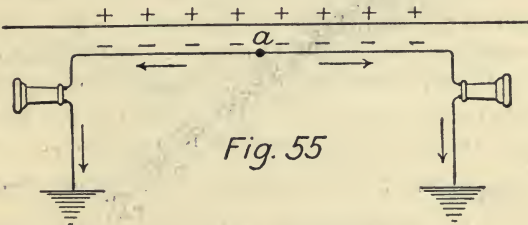


Fig. 55

Suppose, as in Fig. 55, the upper wire has a charge of positive electricity, it will induce a bound negative charge on the upper side of the grounded telephone wire and a free positive charge on its lower side. As this positive charge is free, it will flow from the center of the wire *a* in both directions through the receivers to earth. Let the charge in the upper wire now become negative and the reverse condition will occur, i. e., a positive bound charge will exist in the telephone wire and a positive charge will flow from the earth through the receivers to neutralize the negative free charge on the telephone wire. If the upper wire carries a varying or alternating current the static charge will constantly change, and the induced charge on the telephone circuit will constantly vary and produce a varying flow of electricity through the receivers and render them noisy. If the upper wire carries a telephone current the conversation will be reproduced by electrostatic induction in the second circuit, giving the familiar "cross talk."

If a charged wire is nearer one side of a metallic circuit than the other, as in Fig. 56, the following will be the approximate condition, due to electrostatic induction when the disturbing wire is positively charged: The side *A* will have a negative bound charge, while the side *B* will have a positive one, because at first both *A* and *B*, having negative bound charges on their upper sides and positive

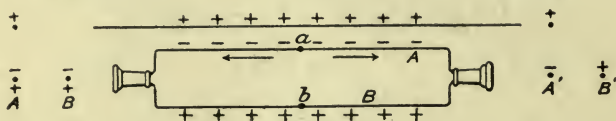


Fig. 56

on their lower sides, as shown in the illustration in Fig. 56, the positive charge on *A* flows in both directions from its middle point, *a*, through the receivers, neutralizing the negative charge on *B*, the positive charge remaining there. Upon the disappearance of the charge from the disturbing wire the positive charge on *B* will flow in both directions from its middle point, *b*, through the receivers and neutralize the negative charge on *A*. If the charge on the disturbing wire is negative, the reverse of the above takes place. If the charge on the disturbing wire varies, a varying inductive charge of opposite signs will exist in each side of the metallic circuit and current flows through both receivers. Neutral points exist at *a* and *b*, and if these are connected by a receiver no noise will be heard in it, although the noise continues in the receivers at each end.

TRANSPPOSITION FOR ELECTROSTATIC INDUCTION.

The amount of electrostatic inductive disturbance depends upon the character of the insulation used and the capacity of the conductor, in addition to the factors mentioned under electrostatic induction.

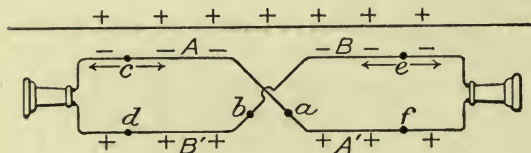


Fig. 57

If the line be transposed once at its center, as in Fig. 57, the noise in the end receivers will be reduced but not entirely eliminated. Each half of each side is a neutral point at *c*, *d*, *e*, and *f*, the charge flowing away from *c* and *e* and toward *d* and *f*, *a* and *b* being no longer neutral. The neutral points are shifted from the center toward the ends, as the impedance of the receivers causes more of

the induced charge to pass through the transposition wires than through themselves. An infinite number of transpositions would theoretically be required to produce silence at the ends of the line, but practice has shown that in long transmission line transpositions at $\frac{1}{4}$ or $\frac{1}{2}$ mile are sufficient.

These transpositions must be so arranged that the circuits are always transposed against one another, thereby avoiding the danger of bringing them back into the same inductive relation as

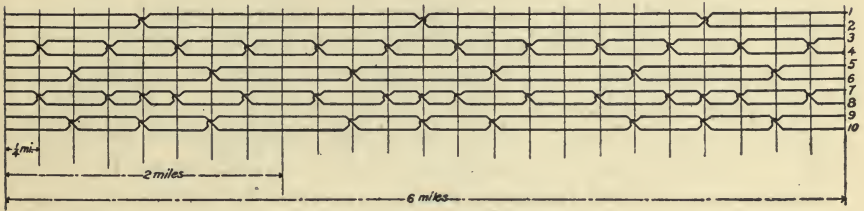
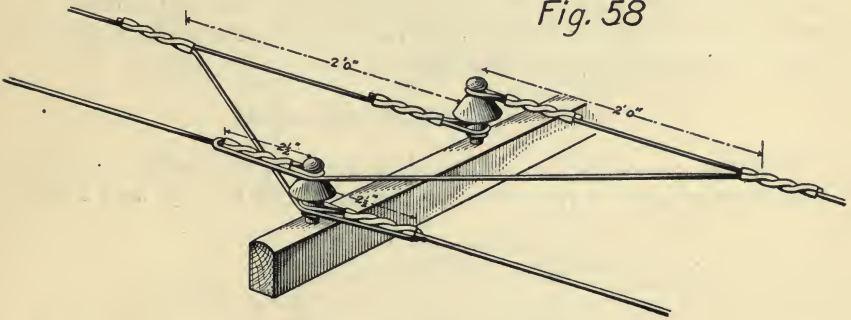


Fig. 58



before. Fig. 58 shows the method of transposition adopted by the American Telegraph and Telephone Company on their long-distance lines.

COMMON RETURN.

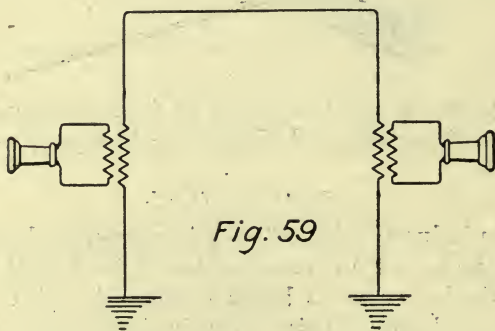
Relief from inductive disturbance in a grounded system can be obtained by the use of a common return wire for all the circuits, one side of the instruments being connected to it and the other side to the lines through their respective line drops on the switch board to the common return. If the lines are thoroughly insulated the return should be insulated throughout, but if one or two of the lines have a low insulation, a ground at the central on the common return will improve the system at the expense of the badly insulated lines. Enough copper must be used in the common return to prevent the current in any one line from branching to the others, while an excess will only aggravate existing trouble. No. 8 B. & S. will prove large enough in all installations of the Signal Corps.

LEAKAGE.

If a ground occurs on one side of a metallic circuit all the induced currents in both sides tend to leak to ground at this point, and increase the noise in all the receivers on the line. If an equal leak exists on both sides of the circuit no increased noise will result, but if the leak becomes too serious the line will be short-circuited and communication interrupted, while a leak on a grounded line reduces the volume of transmission or acts as a short circuit. Less than a millionth of an ampere of foreign variable current will create such a disturbance in the receiver as to render its operation impracticable. It is then evident that when a telephone circuit is crossed by a wire carrying a varying current, the slightest actual flow of current into the circuit will seriously interfere with conversation. The electrical condition of the ground at different localities will frequently show a marked difference of potential, and if a grounded telephone line connects these two points an earth current will be completed through the line and noise will result. The slightest defect in joining or insulating such grounded lines results in serious disturbance.

ELIMINATION OF DISTURBANCES.

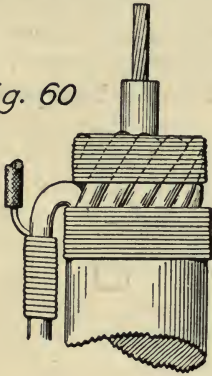
When a grounded line is found to be carrying earth currents the installation of a repeating coil, as shown in Fig. 59, will serve



as a remedy. The introduction of this apparatus will also eliminate the troubles caused by defective contacts within a telephone itself. The impedance and resistance of the repeating coils cuts down the transmission, eliminates many annoying foreign sounds, but transmits enough of the voice current to render conversation audible. When repeating coils are used it is especially necessary to have good grounds. Figs. 60 and 61 show two methods of obtaining this end. When a single-conductor submarine cable is

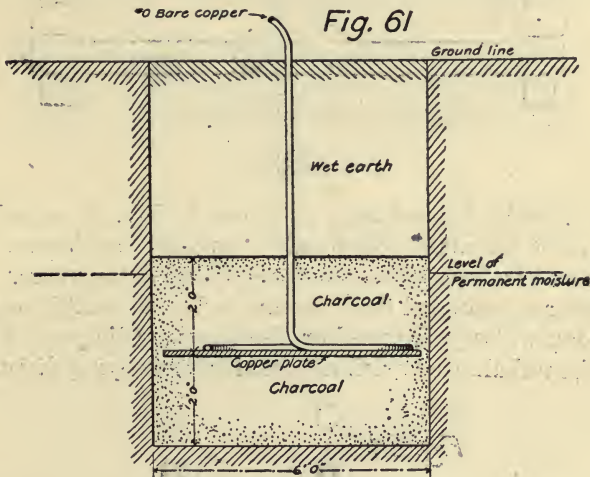
used for telephones only, as in Fig. 60, the armor wire may be used as a ground by bending out one of the strands of armor wire

Fig. 60



and sweating the ground wire to it, taping over the completed joint. An excellent ground is made by embedding a copper ground plate, to which the ground wire is soldered, as shown in Fig. 61, in charcoal below the level of permanent moisture. Merely inserting the ground plate in a running stream of pure water will seldom give a serviceable ground.

Whenever a grounded circuit is paralleled by a power wire for a short distance, repeating coils and a metallic circuit, installed as shown in Fig. 62, will greatly reduce the disturbing effect, especially if the metallic circuit be properly transposed. If the disturbing wire parallels



the circuit for a considerable distance the only remedy is to replace it by a metallic one.

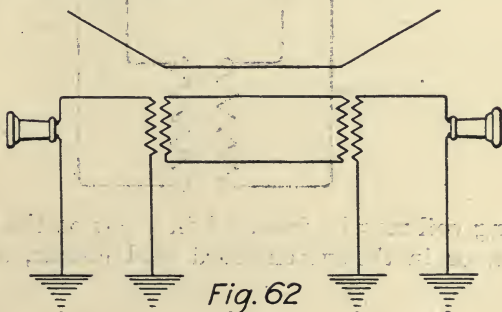
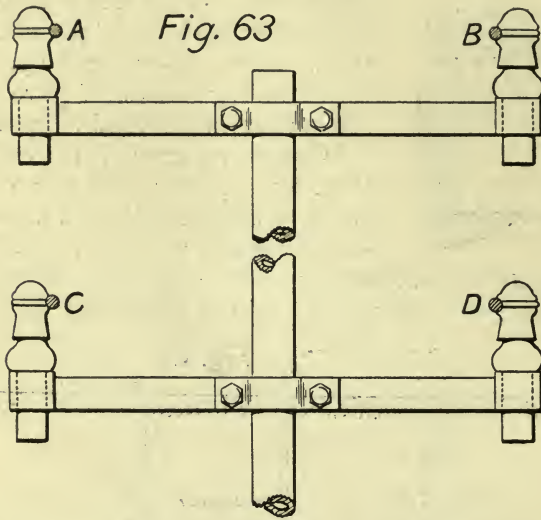


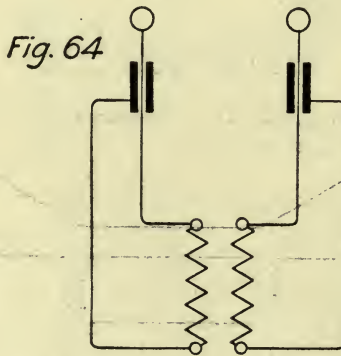
Fig. 62

A grounded line and a metallic circuit may be safely carried on the iron poles of the Signal Corps by using a single insulator at the top of the pole for the grounded circuit and a standard cross arm below for the metallic circuit, the tie on the top insulator being made so as to bring the wire approximately in the center of the insulator. Two metallic lines can be carried on the iron pole by



using the standard cross arm, as shown in Fig. 63, attaching the sides of each circuit to diagonally opposite insulators. In the figure, A and D form one circuit and B and C the other.

Whenever a grounded line is connected to a metallic one repeating coils must always be used or else the metallic part of the current will be unbalanced, with the resulting annoying disturbances.



The repeating coil may be installed in a box on the pole, in the central office, or in the switch-board cord circuit, as shown in Fig. 64.

As the repeating coils seriously retard the ringing current, the above arrangement is advantageous, as the ringing is done outside of the repeating coil.

In certain localities, remote from sources of inductive or other disturbance, a grounded system of lines will give satisfactory service. But as a general rule all circuits installed by the Signal Corps will be metallic. If a grounded system is for any reason contemplated, a series of tests over the district to be covered should be made at different hours of the day before the wiring system is definitely fixed.

Whenever aerial lines run near trolley or alternating-current circuits, the best method of preventing inductive disturbance is to use a lead-covered cable containing twisted pairs, as each twisted pair gives a complete transposition every three inches, and if the lead sheath is grounded, the sheath acts as an additional guard against static charge.

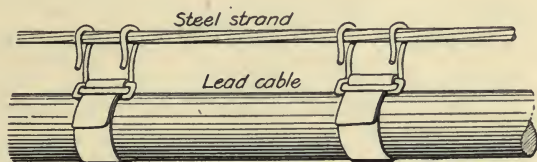


Fig. 65

The usual method of suspending a cable is indicated in Fig. 65.

In the future, the Signal Corps will supply submarine cable that contains twisted pairs for all telephone circuits. Under no circumstances shall a grounded line be connected to one of the wires of a twisted pair except in case of emergency. When it is necessary to connect a grounded line to a pair in a cable it is to be done in the usual way through a repeating coil.

In an emergency, straightaway multiple rubber insulated submarine cable can be used for either telephone circuits, or for a combination of them with others, but the limit of satisfactory operation will, in general, seldom exceed one thousand feet. The standard single-conductor submarine telegraph cable of the Signal Corps can be used satisfactorily for a telephone circuit alone up to a distance of about ten miles by employing a repeating coil with a good ground at each end. Composite circuits (using both telegraph and telephone—see Signal Corps Manual No. 3) can be used on a line up to about five miles, but their use is to be avoided.

INDEX.

	Page.
Arresters, lightning	10
Bell, call	14
Bell, call, Holtzer-Cabot	25
Bell, night	46
Buzzer, field	36
Buzzer, service	34
Cable	73
Circuit, bridging	12
Circuit, grounded	12
Common return	69
Coil, repeating	40, 70, 71
Defective connections	65
Directions, general	9
Disturbances, elimination of	70
Drops	42, 43, 46
Faults in battery	64
Faults; location of	59, 60
Faults, location of, in telephones	60, 61
Faults; location of, in switch boards	63
Faults, summary of	62
Generator, magneto	13
Ground connection	9, 61
Induction, laws of	11
Induction, electro-magnetic	65
Induction, electrostatic	66
Intercommunicating systems	53
Intercommunicating systems, Ericsson	55
Intercommunicating system, Ericsson, wiring of	56
Intercommunicating system, Schmidt	58
Jacks	42, 43, 45
Key, connecting	54
Key, listening	53, 54
Key, ringing	54
Keys, connecting	53
Keys, listening	42, 43, 44, 46
Keys, ringing	42, 42, 44
Keys, ringing and connecting	52
Magneto, Holtzer-Cabot	24
Magneto, Schmidt	23
Magneto, Western Electric	25
Receiver, Bell	26
Receiver, head	28
Receiver, Schmidt	27
Receiver, watch case	28
Speech	11
Switch boards	41

	Page.
Switch board, cordless, 1901 model.....	54
Switch board, cordless, 1901 model, wiring of	55
Switch board, cordless, 1902 model.....	50
Switch board, cordless, 1902 model, wiring of	53
Switch board, Monitor.....	47
Switch board, Monitor, wiring of	48
Switch board, wall cabinet.....	49
Switch board, wall cabinet, wiring of	50
Switch boards, wiring of grounded.....	45
Switch boards, wiring of metallic.....	42
Switching devices	15, 16
Telephone, bridging, wiring of	16
Telephone, cut in	38
Telephone, desk	19
Telephone, field	38
Telephone, location of	59
Telephone, series, wiring of	18
Telephone, service, 1902 model.....	20
Telephone, service, 1901 model.....	21
Telephone, theory of	11
Transmitter, battery	13
Transmitter, gold button	32
Transmitter, solid arm	33
Transmitter, Swedish type.....	31
Transmitter, White, solid back	29
Transposition for electro-magnetic induction	66
Transposition for electrostatic induction	68



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